CONTENTS

1. Units and Measurements 1-33
   - ❖ JEE Main Exercise 1
   - ❖ JEE Advanced Exercise 12
2. Vector and Calculus 34-40
   - ❖ JEE Main Exercise 34
3. Motion in a Straight Line 41-55
   - ❖ JEE Main Exercise 41
   - ❖ JEE Advanced Exercise 47
4. Motion in a Plane 56-74
   - ❖ JEE Main Exercise 56
   - ❖ JEE Advanced Exercise 61
5. Newton's Laws of Motion 75-109
   - ❖ JEE Main Exercise 75
   - ❖ JEE Advanced Exercise 87
6. Work, Power and Energy 110-131
   - ❖ JEE Main Exercise 110
   - ❖ JEE Advanced Exercise 117
7. System of Particles and Centre of Mass 132-156
   - ❖ JEE Main Exercise 132
   - ❖ JEE Advanced Exercise 139
8. Rotational Motion 157-211
   - ❖ JEE Main Exercise 157
   - ❖ JEE Advanced Exercise 171
9. Gravitation 212-241
   - ❖ JEE Main Exercise 212
   - ❖ JEE Advanced Exercise 222
10. Mechanical Properties of Solids 242-255
    - ❖ JEE Main Exercise 242
    - ❖ JEE Advanced Exercise 247
11. Fluid Mechanics 256-290
    - ❖ JEE Main Exercise 256
    - ❖ JEE Advanced Exercise 265
12. Thermal Properties of Matter 291-312
    - ❖ JEE Main Exercise 291
    - ❖ JEE Advanced Exercise 296
13. Kinetic Theory of Gases 313-334
    - ❖ JEE Main Exercise 313
    - ❖ JEE Advanced Exercise 319
14. Thermodynamics 335-366
    - ❖ JEE Main Exercise 335
    - ❖ JEE Advanced Exercise 343
15. Simple Harmonic Motion 367-396
    - ❖ JEE Main Exercise 367
    - ❖ JEE Advanced Exercise 375
16. Waves 397-424
    - ❖ JEE Main Exercise 397
    - ❖ JEE Advanced Exercise 401
17. Electric Charges and Fields 425-455
    - ❖ JEE Main Exercise 425
    - ❖ JEE Advanced Exercise 435
18. Electrostatic Potential and Capacitance 456-502
    - ❖ JEE Main Exercise 456
    - ❖ JEE Advanced Exercise 469

@TAKE_CBSE_X@PAREDUNET

19. Current Electricity 503-560
- JEE Main Exercise 503
- JEE Advanced Exercise 523

20. Moving Charges and Magnetism 561-599
- JEE Main Exercise 561
- JEE Advanced Exercise 571

21. Magnetism and Matter 600-607
- JEE Main Exercise 600
- JEE Advanced Exercise 603

22. Electromagnetic Induction 608-640
- JEE Main Exercise 608
- JEE Advanced Exercise 617

23. Alternating Current 641-664
- JEE Main Exercise 641
- JEE Advanced Exercise 650

24. Electromagnetic Waves 665-678
- JEE Main Exercise 665
- JEE Advanced Exercise 673

25. Ray Optics and Optical Instruments 679-739
- JEE Main Exercise 679
- JEE Advanced Exercise 693

26. Wave Optics 740-764
- JEE Main Exercise 740
- JEE Advanced Exercise 747

27. Dual Nature of Radiation and Matter 765-791
- JEE Main Exercise 765
- JEE Advanced Exercise 774

28. Atoms 792-815
- JEE Main Exercise 792
- JEE Advanced Exercise 797

29. Nuclei 816-834
- JEE Main Exercise 816
- JEE Advanced Exercise 820

30. Semiconductor Electronics: Materials, Devices and Simple Circuits 835-855
- JEE Main Exercise 835

- JEE Advanced Solved Paper-2024 856-867

@FAKE_CBSE X @RAJ_EDUNET

1 Units and Measurements

Scan for Sol.

JEE-Main

Units, System of Units

1. Electric field in a certain region is given by $\vec{E}=\left(\frac{A}{x^2}\hat{i}+\frac{B}{y^3}\hat{j}\right)$.

The SI unit of A and B are: **[30 Jan, 2023 (Shift-I)]**

(a) $Nm^3C^{-1}; Nm^2C^{-1}$ (b) $Nm^2C^{-1}; Nm^3C^{-1}$
(c) $Nm^3C; Nm^2C$ (d) $Nm^2C; Nm^3C$

2. Match List-I with List-II. **[27 Aug, 2021 (Shift-II)]**

List-I		List-II	
A.	R_H (Rydberg constant)	I.	kg m^{-1} s^{-1}
B.	h(Planck's constant)	II.	kg m^2 s^{-1}
C.	μ_B (Magnetic field energy density)	III.	m^{-1}
D.	η(coefficient of viscocity)	IV.	kg m^{-1} s^{-2}

(a) A-II, B-III, C-IV, D-I (b) A-III, B-II, C-IV, D-I
(c) A-III, B-II, C-IV, D-I (d) A-IV, B-II, C-I, D-III

3. If E and H represents the intensity of electric field and magnetising field respectively, then the unit of E/H will be: **[27 Aug, 2021 (Shift-I)]**

(a) Joule (b) Newton
(c) Ohm (d) Mho

4. A physical quantity $\vec{S}$ is defined as $\vec{S}=(\vec{E}\times\vec{B})/\mu_0$, where $\vec{E}$ is electric field, $\vec{B}$ is magnetic field and μ_0 is the permeability of free space. The dimensions of $\vec{S}$ are the same as the dimensions of which of the following quantity (ies)? **[JEE Adv, 2021]**

(a) $\frac{\text{Energy}}{\text{Charge} \times \text{Current}}$ (b) $\frac{\text{Force}}{\text{Length} \times \text{Time}}$
(c) $\frac{\text{Energy}}{\text{Volume}}$ (d) $\frac{\text{Power}}{\text{Area}}$

5. The density of a material in SI units is 128 kg m^{-3}. In certain units in which the unit of length is 25 cm and the unit of mass 50 g, the numerical value of density of the material is **[10 Jan, 2019 (Shift-I)]**

(a) 40 (b) 16
(c) 640 (d) 410

Dimension, Dimensional Formula

6. The dimensional formula of latent heat is: **[09 April, 2024 (Shift-I)]**

(a) $[M^0LT^{-2}]$ (b) $[MLT^{-2}]$
(c) $[M^0L^2T^{-2}]$ (d) $[ML^2T^{-2}]$

7. If ε_0 is the permittivity of free space and E is the electric field, then $\varepsilon_0 E^2$ has the dimensions: **[08 April, 2024 (Shift-II)]**

(a) $[M^0L^{-2}TA]$ (b) $[ML^{-1}T^{-2}]$
(c) $[M^{-1}L^{-3}T^4A^2]$ (d) $[ML^2T^{-2}]$

8. Given below are two statements:

Statement (I): Dimensions of specific heat is $[L^2T^{-2}K^{-1}]$

Statement (II): Dimensions of gas constant is $[ML^2T^{-1}K^{-1}]$

[06 April, 2024 (Shift-II)]

(a) Statement (I) is incorrect but statement (II) is correct
(b) Both statement (I) and statement (II) are incorrect
(c) Statement (I) is correct but statement (II) is incorrect
(d) Both statement (I) and statement (II) are correct

9. Match List I with List II

List-I		List-II	
A.	Torque	I.	$[M^1L^1T^{-2}A^{-2}]$
B.	Magnetic field	II.	$[L^2A^1]$
C.	Magnetic moment	III.	$[M^1T^{-2}A^{-1}]$
D.	Permeability of free space	IV.	$[M^1L^2T^{-2}]$

Choose the correct answer from the options given below: **[06 April, 2024 (Shift-I)]**

(a) A-I, B-III, C-II, D-IV
(b) A-IV, B-III, C-II, D-I
(c) A-III, B-I, C-II, D-IV
(d) A-IV, B-II, C-III, D-I

BEAKER EDUNET

10. What is the dimensional formula of ab^{-1} in the equation $\left(P+\frac{a}{V^2}\right)(V-b)=RT$, where letters have their usual meaning.

[05 April, 2024 (Shift-II)]

(a) $[M^0L^3T^{-2}]$ (b) $[ML^2T^{-2}]$
(c) $[M^{-1}L^3T^3]$ (d) $[M^1L^3T^4]$

11. If G be the gravitational constant and u be the energy density then which of the following quantity have the dimension as that the $\sqrt{uG}$:

[05 April, 2024 (Shift-I)]

(a) Pressure gradient per unit mass
(b) Force per unit mass
(c) Gravitational potential
(d) Energy per unit mass

12. The dimensional formula of angular impulse is:

[1 Feb, 2024 (Shift-I)]

(a) $[M\,L^{-2}\,T^{-1}]$ (b) $[M\,L^2\,T^{-2}]$
(c) $[M\,L\,T^{-1}]$ (d) $[M\,L^2\,T^{-1}]$

13. Given below are two statements: [27 Jan, 2024 (Shift-I)]

Statement-I: Planck's constant and angular momentum have same dimensions.

Statement-II: Linear momentum and moment of force have same dimensions.

In the light of the above statements, choose the correct answer from the options given below:

(a) Statement-I is true but Statement-II is false
(b) Both Statement-I and Statement-II are false
(c) Both Statement-I and Statement-II are true
(d) Statement-I is false but Statement-II is true

14. Match List-I with List-II. [30 Jan, 2024 (Shift-I)]

	List-I		List-II
A.	Coefficient of viscosity	I.	$[M\,L^2T^{-2}]$
B.	Surface Tension	II.	$[M\,L^2T^{-1}]$
C.	Angular momentum	III.	$[M\,L^{-1}T^{-1}]$
D.	Rotational kinetic energy	IV.	$[M\,L^0T^{-2}]$

(a) A-II, B-I, C-IV, D-III (b) A-I, B-II, C-III, D-IV
(c) A-III, B-IV, C-II, D-I (d) A-IV, B-III, C-II, D-I

15. Match List-I with List-II.

	List-I		List-II
A.	Young's Modulus (Y)	I.	$[ML^{-1}T^{-1}]$
B.	Coefficient of Viscosity (η)	II.	$[ML^2T^{-1}]$
C.	Planck's Constant (h)	III.	$[ML^{-1}T^{-2}]$
D.	Work Function (ϕ)	IV.	$[ML^2T^{-2}]$

Choose the correct answer from the options given below:

[25 Jan, 2023 (Shift-II)]

(a) A-II, B-III, C-IV, D-I
(b) A-III, B-I, C-II, D-IV
(c) A-I, B-III, C-IV, D-II
(d) A-I, B-II, C-III, D-IV

16. Match List-I with List-II:

	List-I (Physical Quantity)		List-II (Dimensional Formula)
A.	Pressure gradient	I.	$[M^1L^2T^{-2}]$
B.	Energy density	II.	$[M^1L^{-1}T^{-2}]$
C.	Electric Field	III.	$[M^1L^{-2}T^{-2}]$
D.	Latent heat	IV.	$[M^0L^1T^{-2}A^{-1}]$

Choose the correct answer from the options given below:

[29 Jan, 2023 (Shift-I)]

(a) A-III, B-II, C-I, D-IV (b) A-II, B-III, C-IV, D-I
(c) A-III, B-II, C-IV, D-I (d) A-II, B-III, C-I, D-IV

17. Match List-I with List-II

	List-I		List-II
A.	Surface tension	I.	$Kgm^{-1}s^{-1}$
B.	Pressure	II.	$Kgms^{-2}$
C.	Viscosity	III.	$Kgm^{-1}s^{-2}$
D.	Impulse	IV.	Kgs^{-2}

Choose the correct answer from the options given below :

[25 Jan, 2023 (Shift-I)]

(a) A-(IV), B-(III), C-(II), D-(I)
(b) A-(IV), B-(III), C-(I), D-(II)
(c) A-(III), B-(IV), C-(I), D-(II)
(d) A-(II), B-(I), C-(III), D-(IV)

18. Match List-I with List-II

	List-I		List-II
A.	Spring constant	I.	(T^{-1})
B.	Angular speed	II.	(MT^{-2})
C.	Angular momentum	III.	(ML^2)
D.	Moment of Inertia	IV.	(ML^2T^{-1})

Choose the correct answer from the options given below:

[12 April, 2023 (Shift-I)]

(a) A-II, B-I, C-IV, D-III (b) A-IV, B-I, C-III, D-II
(c) A-II, B-III, C-I, D-IV (d) A-I, B-III, C-II, D-IV

19. Match List-I with List-II.

	List-I		List-II
A.	Angular momentum	I.	$[ML^2\,T^{-2}]$
B.	Torque	II.	$[ML^{-1}\,T^{-2}]$
C.	Stress	III.	$[ML^2\,T^{-1}]$
D.	Pressure gradient	IV.	$[ML^{-1}\,T^{-2}]$

Choose the correct answer from the options given below:

[31 Jan, 2023 (Shift-I)]

(a) A-I, B-IV, C-III, D-II (b) A-III, B-I, C-IV, D-II
(c) A-II, B-III, C-IV, D-I (d) A-IV, B-II, C-I, D-III

20. Match List-I with List-II.

	List-I		List-II
A.	Torque	I.	$kg\ m^{-1}\ s^{-2}$
B.	Energy density	II.	$kg\ ms^{-1}$
C.	Pressure gradient	III.	$kg\ m^{-2}\ s^{-2}$
D.	Impulse	IV.	$kg\ m^2\ s^{-2}$

@JEE_ADDICTIVE_OFFICIAL

Choose the correct answer from the options given below:

[30 Jan, 2023 (Shift-II)]

(a) A-IV, B-III, C-I, D-II (b) A-I, B-IV, C-III, D-II
(c) A-IV, B-I, C-II, D-III (d) A-IV, B-I, C-III, D-II

21. Dimension of $\frac{1}{\mu_0 \in_0}$ should be equal to [8 April, 2023 (Shift-I)]

(a) T^2/L^2 (b) L/T (c) L^2/T^2 (d) T/L

22. Match List-I with List-II

	List-I		List-II
A.	Planck's constant (h)	I.	$[M^1 L^2 T^{-2}]$
B.	Stopping potential (Vs)	II.	$[M^1 L^1 T^{-1}]$
C.	Work function (ϕ)	III.	$[M^1 L^2 T^{-1}]$
D.	Momentum (p)	IV.	$[M^1 L^2 T^{-3} A^{-1}]$

[24 Jan, 2023 (Shift-I)]

(a) A-III, B-I, C-II, D-IV (b) A-III, B-IV, C-I, D-II
(c) A-II, B-IV, C-III, D-I (d) A-I, B-III, C-IV, D-II

23. Identify the pair of physical quantities that have same dimensions:

[24 June, 2022 (Shift-II)]

(a) Velocity gradient and decay constant
(b) Wien's constant and Stefan constant
(c) Angular frequency and angular momentum
(d) Wave number and Avogadro number

24. The dimension of mutual inductance is:

[26 June, 2022 (Shift-II)]

(a) $[ML^2 T^{-2}A^{-1}]$ (b) $[ML^2 T^{-3}A^{-1}]$
(c) $[ML^2 T^{-2}A^{-2}]$ (d) $[ML^2 T^{-3}A^{-2}]$

25. The SI unit of a physical quantity is pascal-second. The dimensional formula of this quantity will be [27 June, 2022 (Shift-II)]

(a) $[ML^{-1}T^{-1}]$ (b) $[ML^{-1}T^{-2}]$
(c) $[ML^2T^{-1}]$ (d) $[M^{-1}L^3T^0]$

26. If momentum [P], area [A] and time [T] are taken as fundamental quantities, then the dimensional formula for coefficient of viscosity is: [25 July, 2022 (Shift-I)]

(a) $[PA^{-1}T^0]$ (b) $[PAT^{-1}]$
(c) $[PA^{-1}T]$ (d) $[PA^{-1}T^{-1}]$

27. The dimensions of $\left(\frac{B^2}{\mu_0}\right)$ will be

(if μ_0 : permeability of free space and B : magnetic field)

[28 July, 2022 (Shift-I)]

(a) $\left[ML^2 T^{-2}\right]$ (b) $\left[MLT^{-2}\right]$
(c) $\left[ML^{-1} T^{-2}\right]$ (d) $\left[ML^2 T^{-2} A^{-1}\right]$

28. Which of the following physical quantities have the same dimensions? [25 July, 2022 (Shift-I)]

(a) Electric displacement ($\vec{D}$) and surface charge density
(b) Displacement current and electric field
(c) Current density and surface charge density
(d) Electric potential and energy

29. Match Column-I with Column-II.

	Column-I		Column-II
A.	Torque	p.	Nms^{-1}
B.	Stress	q.	$J\,kg^{-1}$
C.	Latent heat	r.	Nm
D.	Power	s.	Nm^{-2}

Choose the correct answer from the options given below

[29 July, 2022 (Shift-II)]

(a) A-(r); B-(q); C-(p); D-(s)
(b) A-(r); B-(s); C-(q); D-(p)
(c) A-(s); B-(p); C-(r); D-(q)
(d) A-(q); B-(r); C-(p); D-(s)

30. Identify the pair of physical quantities which have different dimensions: [24 June, 2022 (Shift-I)]

(a) Wave number and Rydberg's constant.
(b) Stress and Coefficient of elasticity.
(c) Coercivity and Magnetisation.
(d) Specific heat capacity and Latent heat.

31. Match List-I with List-II. [27 July, 2021 (Shift-II)]

	List-I		List-II
A.	Capacitance, C	I.	$M^1L^1T^{-3}A^{-1}$
B.	Permittivity of free space, ϵ_0	II.	$M^{-1}L^{-3}T^4A^2$
C.	Permeability of free space, μ_0	III.	$M^{-1}L^{-2}T^4A^2$
D.	Electric field, E	IV.	$ML^1T^{-2}A^{-2}$

Choose the correct answer from the options given below:

(a) A-III, B-II, C-IV, D-I (b) A-III, B-IV, C-II, D-I
(c) A-IV, B-II, C-III, D-I (d) A-IV, B-III, C-II, D-I

32. If E, L, M and G denote the quantities as energy, angular momentum, mass and constant of gravitation respectively, then the dimensions of P in the formula $P = EL^2M^{-5}G^{-2}$ are :- [26 Aug, 2021 (Shift-I)]

(a) $[M^0 L^0 T^0]$ (b) $[M^1L^1T^{-2}]$
(c) $[M^0 L^1 T^0]$ (d) $[M^{-1}L^{-1}T^2]$

33. If 'C' and 'V' represent capacity and voltage respectively then what are the dimensions of λ where $C/V = \lambda$? [26 Feb, 2021 (Shift-II)]

(a) $[M^{-1}L^{-3}I^2T^{-7}]$ (b) $[M^2L^{-3}I^2T^6]$
(c) $[M^{-3}L^{-4}I^2T^7]$ (d) $[M^2L^{-4}I^2T^7]$

34. Which of the following is not a dimensionless quantity? [27 Aug, 2021 (Shift-I)]

(a) Relative magnetic permeability (μ_r)
(b) Power factor
(c) Quality factor
(d) Permeability of free space (μ_0)

35. Match List-I with List-II: [25 Feb, 2021 (Shift-I)]

	List-I		List-I
A.	h (Planck's constant)	I.	$[MLT^{-1}]$
B.	E (kinetic energy)	II.	$[ML^2T^{-1}]$
C.	V (electric potential)	III.	$[ML^2T^{-2}]$
D.	P (liner momentum)	IV.	$[ML^2I^1T^{-3}]$

Choose the correct answer from the options given below:

(a) A-I, B-II, C-IV, D-III (b) A-III, B-II, C-IV, D-I
(c) A-II, B-III, C-IV, D-I (d) A-III, B-IV, C-II, D-I

@FAKE CBSE X @FREEDUNET

36. If force (F), length (L) and time (T) are taken as the fundamental quantities. Then what will be the dimension of density:
[27 Aug, 2021 (Shift-II)]
(a) $[FL^{-3}T^2]$ (b) $[FL^{-3}T^3]$
(c) $[FL^{-4}T^2]$ (d) $[FL^{-3}T^1]$

37. Match List-I with List-II. [31 Aug, 2021 (Shift-I)]

List-I		List-II	
A.	Torque	I.	MLT^{-1}
B.	Impulse	II.	MT^{-2}
C.	Tension	III.	ML^2T^{-2}
D.	Surface Tension	IV.	MLT^{-2}

Choose the most appropriate answer from the option given below:
(a) A-II, B-I, C-IV, D-III (b) A-I, B-III, C-IV, D-II
(c) A-III, B-I, C-IV, D-II (d) A-III, B-IV, C-I, D-II

38. If surface tension (S), Moment of inertia (I) and Planck's constant (h), were to be taken as the fundamental units, the dimensional formula for linear momentum would be
[8 April, 2019 (Shift-II)]
(a) $S^{1/2}I^{1/2}h^0$ (b) $S^{1/2}I^{1/2}h^0$
(c) $S^{1/2}I^{1/2}h^{-1}$ (d) $S^{1/2}I^{1/2}h^{-1}$

39. Which of the following combinations has the dimension of electrical resistance (ϵ_0 is the permittivity of vacuum and μ_0 is the permeability of vacuum)? [12 April, 2019 (Shift-I)]
(a) $\sqrt{\frac{\epsilon_0}{\mu_0}}$ (b) $\frac{\mu_0}{\epsilon_0}$ (c) $\frac{\epsilon_0}{\mu_0}$ (d) $\sqrt{\frac{\mu_0}{\epsilon_0}}$

40. In SI units, the dimensions of $\sqrt{\frac{\epsilon_0}{\mu_0}}$ is: [8 April, 2019 (Shift-I)]
(a) $[AT^{-3}ML^{3/2}]$ (b) $[A^{-1}TML^3]$
(c) $[A^2T^3M^{-1}L^{-2}]$ (d) $[AT^2M^{-1}L^{-1}]$

Dimensional Analysis, Principle of Homogeneity

41. Applying the principle of homogeneity of dimensions, determine which one is correct.
where T is time period, G is gravitational constant, M is mass, r is radius of orbit. [04 April, 2024 (Shift-II)]
(a) $T^2=\frac{4\pi^2 r}{GM^2}$ (b) $T^2=4\pi^2 r^3$
(c) $T^2=\frac{4\pi^2 r^3}{GM}$ (d) $T^2=\frac{4\pi^2 r^2}{GM}$

42. Consider two physical quantities A and B related to each other as $E=\frac{B-x^2}{At}$ where E, x and t have dimensions of energy, length and time respectively. The dimension of AB is
[31 Jan, 2024 (Shift-II)]
(a) $L^{-2}M^1T^0$ (b) $L^2M^{-1}T^1$
(c) $L^{-2}M^{-1}T^1$ (d) $L^0M^{-1}T^1$

43. A force is represented by $F = ax^2 + bt^{1/2}$ Where x = distance and t = time. The dimensions of b^2/a are: [31 Jan, 2024 (Shift-I)]
(a) $[ML^3T^{-3}]$ (b) $[MLT^{-2}]$
(c) $[ML^{-1}T^{-1}]$ (d) $[ML^2T^{-3}]$

44. If mass is written as $m = k\,c^p\,G^{-1/2}\,h^{1/2}$ then the value of P will be: (Constants have their usual meaning with k a dimensionless constant) [30 Jan, 2024 (Shift-II)]
(a) 1/2 (b) 1/3 (c) 2 (d) −1/3

45. The equation of state of a real gas is given by $\left(P+\frac{a}{V^2}\right)(V-b)=RT$, where P, V and T are pressure, volume and temperature respectively and R is the universal gas constant. The dimensions of $\frac{a}{b^2}$ is similar to that of:
[27 Jan, 2024 (Shift-II)]
(a) PV (b) P
(c) RT (d) R

46. If the velocity of light c, universal gravitational constant G and planck's constant h are chosen as fundamental quantities. The dimensions of mass in the new system is:
[1 Feb, 2023 (Shift-II)]
(a) $\left[h^{\frac{1}{2}}c^{-\frac{1}{2}}G^{1}\right]$ (b) $\left[h^{1}c^{1}G^{-1}\right]$
(c) $\left[h^{-\frac{1}{2}}c^{\frac{1}{2}}G^{\frac{1}{2}}\right]$ (d) $\left[h^{\frac{1}{2}}c^{\frac{1}{2}}G^{-\frac{1}{2}}\right]$

47. $\left(P+\frac{a}{V^2}\right)(V-b)=RT$ represents the equation of state of some gases. Where P is the pressure, V is the volume, T is the temperature and a, b, R are the constants. The physical quantity, which has dimensional formula as that of $\frac{b^2}{a}$, will be:
[1 Feb, 2023 (Shift-I)]
(a) Bulk modulus (b) Modulus of rigidity
(c) Compressibility (d) Energy density

48. The equation of a circle is given by $x^2+y^2=a^2$, where a is the radius. If the equation is modified to change the origin other than (0, 0), then find out the correct dimensions of A and B in a new equation: $(x-At)^2+\left(y-\frac{t}{B}\right)^2=a^2$. The dimensions of t is given as $[T^{-1}]$.
[29 Jan, 2023 (Shift-II)]
(a) $A=\left[L^{-1}T\right], B=\left[LT^{-1}\right]$
(b) $A=\left[LT\right], B=\left[L^{-1}T^{-1}\right]$
(c) $A=\left[L^{-1}T^{-1}\right], B=\left[LT^{-1}\right]$
(d) $A=\left[L^{-1}T^{-1}\right], B=\left[LT\right]$

49. The frequency (ν) of an oscillating liquid drop may depend upon radius (r) of the drop, density (ρ) of liquid and the surface tension (s) of the liquid as: $\nu=r^a\rho^b s^c$. The values of a, b and c respectively are [24 Jan, 2023 (Shift-II)]
(a) $\left(-\frac{3}{2},-\frac{1}{2},\frac{1}{2}\right)$ (b) $\left(\frac{3}{2},-\frac{1}{2},\frac{1}{2}\right)$
(c) $\left(\frac{3}{2},\frac{1}{2},-\frac{1}{2}\right)$ (d) $\left(-\frac{3}{2},\frac{1}{2},\frac{1}{2}\right)$

50. If force (F), velocity (V) and time (T) are considered as fundamental physical quantity, then dimensional formula of density will be:
[11 Apr, 2023 (Shift-II)]
(a) $FV^{-2}T^2$ (b) $FV^{-4}T^{-2}$
(c) FV^4T^{-6} (c) $F^2V^2T^2$

@FAKE_CBSE_X@RAJ_EDUNET

51. In the equation $\left[X+\frac{a}{Y^2}\right][Y-b]=RT$, X is pressure, Y is volume, R is universal gas constant and T is temperature. The physical quantity equivalent to the ratio $\frac{a}{b}$ is: **[13 Apr, 2023 (Shift-II)]**

(a) Energy (b) Impulse
(c) Pressure gradient (d) Coefficient of viscosity

52. Young's modulus of elasticity Y is expressed in terms of three derived quantities, namely, the gravitational constant G, Planck's constant h and the speed of light c, as $Y=c^{\alpha}h^{\beta}G^{\gamma}$. Which of the following is the correct option ? **[JEE Adv, 2023]**

(a) $\alpha=7,\beta=-1,\gamma=-2$ (b) $\alpha=-7,\beta=-1,\gamma=-2$
(c) $\alpha=7,\beta=-1,\gamma=2$ (d) $\alpha=-7,\beta=1,\gamma=-2$

53. Velocity (υ) and acceleration (a) in two systems of units 1 and 2 are related as $\upsilon_2=\frac{n}{m^2}\upsilon_1$ and $a_2=\frac{a_1}{mn}$ respectively. Here m and n are constants. The relations for distance and time in two system respectively are: **[28 June, 2022 (Shift-II)]**

(a) $\frac{n^3}{m^3}L_1=L_2$ and $\frac{n^2}{m}T_1=T_2$

(b) $L_1=\frac{n^4}{m^2}L_2$ and $T_1=\frac{n^2}{m}T_2$

(c) $L_1=\frac{n^2}{m}L_2$ and $T_1=\frac{n^4}{m^2}T_2$

(d) $\frac{n^2}{m}L_1=L_2$ and $\frac{n^4}{m^2}T_1=T_2$

54. An expression of energy density is given by $u=\frac{\alpha}{\beta}\sin\left(\frac{\alpha x}{kt}\right)$, where α, β are constants, x is displacement, k is Boltzmann constant and t is the temperature. The dimensions of β will be: **[27 July, 2022 (Shift-II)]**

(a) $\left[ML^2T^{-2}\theta^{-1}\right]$ (b) $\left[M^0L^2T^{-2}\right]$
(c) $\left[M^0L^0T^0\right]$ (d) $\left[M^0L^2T^0\right]$

55. Consider the efficiency of Carnot's engine is given by $\eta=\frac{\alpha\beta}{\sin\theta}\log_e\frac{\beta x}{kT}$, where α and β are constants. If T is temperature, k is Boltzmann constant, θ is angular displacement and x has the dimensions of length. Then, choose the incorrect option. **[28 July, 2022 (Shift-II)]**

(a) Dimension of β is same as that of force.
(b) Dimension of $\alpha^{-1}x$ is same as that of energy.
(c) Dimension of $\eta^{-1}\sin\theta$ is same of $\alpha\beta$.
(d) Dimension of α is same of β.

56. An expression for a dimensionless quantity P is given by $P=\frac{\alpha}{\beta}\log_e\left(\frac{kt}{\beta x}\right)$; where α and β are constants, x is distance; k is Boltzmann constant and t is the temperature. Then the dimensions of α will be: **[26 June, 2022 (Shift-I)]**

(a) $[M^0L^{-1}T^0]$
(b) $[ML^0T^{-2}]$
(c) $[MLT^{-2}]$
(d) $[ML^2T^{-2}]$

57. In Vander Waals equation $\left[P+\frac{a}{V^2}\right][V-b]=RT$; P is pressure. V is volume, R is universal gas constant and T is temperature. The ratio of constants a/b is dimensionally equal to **[29 June, 2022 (Shift-I)]**

(a) P/V (b) V/P (c) PV (d) PV^2

58. In a particular system of units, a physical quantity can be expressed in terms of the electric charge e, electron mass m_e, Planck's constant h, and coulomb's constant $k=\frac{1}{4\pi\varepsilon_0}$, where ε_0 is the permittivity of vacuum. In terms of these physical constants, the dimension of the magnetic field is $[B]=[e]^{\alpha}[m_e]^{\beta}[h]^{\gamma}[k]^{\delta}$. The value of $\alpha+\beta+\gamma+\delta$ is _____. **[JEE Adv, 2022]**

59. If time (t), velocity (v), and angular momentum (ℓ) are taken as the fundamental units. Then the dimension of mass (m) in terms of t, v, and ℓ is: **[20 July, 2021 (Shift-II)]**

(a) $[t^{-2}v^{-1}\ell^1]$ (b) $[t^{-1}v^1\ell^{-2}]$
(c) $[t^{-1}v^{-2}\ell^1]$ (d) $[t^1v^2\ell^{-1}]$

60. In a typical combustion engine the work done by a gas molecule is given by $W=\alpha^2\beta e^{-\frac{\beta x^2}{kT}}$, where x is the displacement, k is the Boltzmann constant and T is the temperature. If α and β are constants, dimensions of α will be : **[26 Feb, 2021 (Shift-I)]**

(a) $[MLT^{-1}]$ (b) $[M^0LT^0]$
(c) $[M^2LT^{-2}]$ (d) $[MLT^{-2}]$

61. Which of the following equations is dimensionally incorrect? Where t = time, h = height, s = surface tension, θ = angle, ρ = density, r = radius, g = acceleration due to gravity, v = volume, p = pressure, W = work done, τ = torque, ϵ = permittivity, E = electric field, J = current density, L = length. **[31 Aug, 2021 (Shift-I)]**

(a) $W=\tau\theta$ (b) $h=\frac{2s\cos\theta}{\rho rg}$
(c) $v=\frac{\pi pa^4}{8\eta L}$ (d) $J=\epsilon\frac{\partial E}{\partial t}$

62. If e is the electronic charge, c is the speed of light in free space and h is Planck's constant, the quantity $\frac{1}{4\pi\varepsilon_0}\frac{|e|^2}{hc}$ has dimensions of: **[25 Feb, 2021 (Shift-II)]**

(a) $[ML\,T^0]$ (b) $[ML\,T^{-1}]$ (c) $[M^0L^0T^0]$ (d) $[L\,C^{-1}]$

63. The work done by a gas molecule in an isolated system is given by $W=\alpha\beta^2e^{-\frac{x^2}{\alpha kT}}$, where x is the displacement, k is the Boltzmann constant and T is the temperature. α and β are constants. Then the dimensions of β will be: **[24 Feb, 2021 (Shift-I)]**

(a) $[MLT^{-2}]$ (b) $[ML^2T^{-2}]$ (c) $[M^2LT^2]$ (d) $[M^0LT^0]$

64. If velocity [V], time [T] and force [F] are chosen as the base quantities, the dimensions of the mass will be : **[31 Aug, 2021 (Shift-II)]**

(a) $[FT^2\,V]$ (b) $[FTV^{-1}]$ (c) $[FVT^{-1}]$ (d) $[FT^{-1}\,V^{-1}]$

65. The force is given in terms of time t and displacement x by the equation $F=A\cos Bx+C\sin Dt$. The dimensional formula of AD/B is **[25 July, 2021 (Shift-II)]**

(a) $[M^1L^2T^{-3}]$ (b) $[M^1L^1T^{-2}]$
(c) $[ML^2T^{-3}]$ (d) $[M^1LT^{-1}]$

66. The dimension of stopping potential V_0 in photoelectric effect in units of Planck's constant 'h', speed of light 'c' and Gravitational constant 'G' and ampere A is: **[24 Feb, 2021 (Shift-I)]**

(a) $h^{1/3}G^{2/3}c^{1/3}A^{-1}$ (b) $h^{-2/3}c^{-1/3}G^{4/3}A^{-1}$
(c) $h^{2/3}c^{5/3}G^{1/3}A^{-1}$ (d) $h^2G^{3/2}c^{1/3}A^{-1}$

@FREE_OBSEX@FREE.NET

67. Dimensional formula for thermal conductivity is (here K denotes the temperature): [04 Sep, 2020 (Shift-I)]
(a) $MLT^{-3}K^{-1}$ (b) $MLT^{-2}K^{-2}$
(c) $MLT^{-2}K$ (d) $MLT^{-3}K$

68. Amount of solar energy received on the earth's surface per unit area per unit time is defined a solar constant. Dimension of solar constant is [3 Sep, 2020 (Shift-II)]
(a) ML^2T^{-2} (b) MLT^{-2} (c) $M^1L^0T^{-1}$ (d) ML^0T^{-3}

69. A quantity x is given by (IFv^2/WL^4) in terms of moment of inertia I, force F, velocity v, work W and length L. The dimensional formula for x is same as that of [04 Sep, 2020 (Shift-II)]
(a) Coefficient of viscosity (b) Force constant
(c) Energy density (d) Planck's constant

70. A quantity f is given by $f=\sqrt{\frac{hc^5}{G}}$ where c is speed of light, G universal gravitational constant and h is the Planck's constant. Dimension of f is that of: [9 Jan, 2020 (Shift-I)]
(a) energy (b) momentum
(c) area (d) volume

71. If speed V, area A and force F are chosen as fundamental units, then the dimension of Young's modulus will be [2 Sep, 2020 (Shift-I)]
(a) $FA^{-1}V^0$ (b) FA^2V^{-1} (c) FA^2V^{-2} (d) FA^2V^{-3}

72. If momentum (P), area (A) and time (T) are taken to be the fundamental quantities then the dimensional formula for energy is [2 Sep, 2020 (Shift-II)]
(a) $\left[P^{\frac{1}{2}}AT^{-1}\right]$ (b) $[P^1AT^{-2}]$
(c) $\left[PA^{\frac{1}{2}}T^{-1}\right]$ (b) $[PA^{-1}T^{-2}]$

73. The quantities $x=\frac{1}{\sqrt{\mu_0\varepsilon_0}}$, $y=\frac{E}{B}$ and $z=\frac{I}{CR}$ are defined where C-capacitance, R-resistance, l-length, E-electric field, B-magnetic field and ε_0, μ_0-free space permitivity and permeability respectively. Then [5 Sep, 2020 (Shift-II)]
(a) Only x and y have the same dimension.
(b) Only x and z have the same dimension.
(c) x, y and z have the same dimension.
(d) Only y and z have the same dimension.

74. Sometimes it is convenient to construct a system of units so that all quantities can be expressed in terms of only one physical quantity. In one such system, dimensions of different quantities are given in terms of a quantity x as follows: [position] = $[x^\alpha]$; [speed] = $[x^\beta]$; [acceleration] = $[x^p]$; [linear momentum] = $[x^q]$; [force] = $[x^r]$. Then [JEE Adv, 2020]
(a) $\alpha+p=2\beta$ (b) $p+q-r=\beta$
(c) $p-q+r=\alpha$ (d) $p+q+r=\beta$

75. Expression for time in terms of G (universal gravitational constant), h (Planck constant) and c (speed of light) is proportional to: [9 Jan, 2019 (Shift-II)]
(a) $\sqrt{\frac{hc^5}{G}}$ (b) $\sqrt{\frac{c^3}{Gh}}$
(c) $\sqrt{\frac{Gh}{c^5}}$ (d) $\sqrt{\frac{Gh}{c^3}}$

76. The force of interaction between two atoms is given by $F=\alpha\beta exp\left(-\frac{x^2}{\alpha kt}\right)$; where x is the distance, k is the Boltzmann constant and T is temperature and α and β are two constants. The dimension of β is: [11 Jan, 2019 (Shift-I)]
(a) $[M^0L^2T^{-4}]$ (b) $[M^1LT^{-4}]$
(c) $[MLT^{-2}]$ (d) $[M^1L^2T^{-2}]$

77. If speed (V), acceleration (A) and force (F) are considered as fundamental units, the dimension of Young's modulus will be: [11 Jan, 2019 (Shift-II)]
(a) $V^{-2}A^2F^{-2}$ (b) $V^{-2}A^2F^2$ (c) $V^4A^{-2}F$ (d) V^4A^2F

78. Let L, R, C and V represent inductance, resistance, capacitance and voltage, respectively. The dimension of $\frac{L}{RCV}$ in SI units will be: [12 Jan, 2019 (Shift-II)]
(a) $[LA^{-2}]$ (b) $[A^{-1}]$ (c) $[LTA]$ (d) $[LT^2]$

79. Let us consider a system of units in which mass and angular momentum are dimensionless. If length has dimension of L, which of the following statement(s) is/are correct? [JEE Adv, 2019]
(a) The dimension of force is L^{-3}.
(b) The dimension of energy of L^{-2}.
(c) The dimension of power is L^{-5}.
(d) The dimension of linear momentum is L^{-1}.

Errors in Measurement

80. Young's modulus is determined by the equation given by $Y=49000\frac{m}{\ell}\frac{dyne}{cm^2}$ where m is the mass and ℓ is the extension of wire used in the experiment. Now error in Young modules (Y) is estimated by taking data from m-ℓ plot in graph paper. The smallest scale divisions are 5 g and 0.02 cm along load axis and extension axis respectively. If the value of m and ℓ are 500 g and 2 cm respectively then percentage error of Y is: [08 April, 2024 (Shift-I)]
(a) 0.2% (b) 0.02% (c) 2% (d) 0.5%

81. In an expression $a\times10^b$: [08 April, 2024 (Shift-I)]
(a) a is order of magnitude for $b\le5$
(b) b is order of magnitude for $a\le5$
(c) b is order of magnitude for $5<a\le10$
(d) b is order of magnitude for $a\ge5$

82. To find the spring constant (k) of a spring experimentally, a student commits 2% positive error in the measurement of time and 1% negative error in measurement of mass. The percentage error in determining value of k is: [06 April, 2024 (Shift-I)]
(a) 3% (b) 1% (c) 4% (d) 5%

83. Time periods of oscillation of the same simple pendulum measured using four different measuring clocks were recorded as 4.62 s, 4.632 s, 4.6 s and 4.64 s. The arithmetic mean of these reading correct significant figure is. [05 April, 2024 (Shift-I)]
(a) 4.623 s (b) 4.62 s
(c) 4.6 s (d) 5 s

@IITJEE_OBSESSION @RAJEEDUNET

84. In an experiment to measure focal length (f) of convex lens, the least counts of the measuring scales for the position of object (u) and for the position of image (v) are Δu and Δv, respectively. The error in the measurement of the focal length of the convex lens will be: [04 April, 2024 (Shift-I)]

(a) $\frac{\Delta u}{u}+\frac{\Delta v}{v}$ (b) $f^2\left[\frac{\Delta u}{u^2}+\frac{\Delta v}{v^2}\right]$

(c) $2f\left[\frac{\Delta u}{u}+\frac{\Delta v}{v}\right]$ (d) $f\left[\frac{\Delta u}{u}+\frac{\Delta v}{v}\right]$

85. Match List-I with List-II.

	List-I (Number)		List-II (Significant figure)
(A)	1001	(I)	3
(B)	010.1	(II)	4
(C)	100.100	(III)	5
(D)	0.0010010	(IV)	6

Choose the correct answer from the options given below: [1 Feb, 2024 (Shift-II)]

(a) (A)-(III), (B)-(IV), (C)-(II), (D)-(I)
(b) (A)-(IV), (B)-(III), (C)-(I), (D)-(II)
(c) (A)-(II), (B)-(I), (C)-(IV), (D)-(III)
(d) (A)-(I), (B)-(II), (C)-(III), (D)-(IV)

86. The radius (r), length (l) and resistance (R) of a metal wire was measured in the laboratory as

$r=(0.35\pm0.05)$ cm, $R=(100\pm10)$ ohm, $l=(15\pm0.2)$ cm

The percentage error in resistivity of the material of the wire is: [1 Feb, 2024 (Shift-I)]

(a) 25.6% (b) 39.9% (c) 37.3% (d) 35.6%

87. The measured value of the length of a simple pendulum is 20 cm with 2 mm accuracy. The time for 50 oscillations was measured to be 40 seconds with 1 second resolution. From these measurements, the accuracy in the measurement of acceleration due to gravity is N%. The value of N is: [31 Jan, 2024 (Shift-II)]

(a) 4 (b) 8 (c) 6 (d) 5

88. If the percentage errors in measuring the length and the diameter of a wire are 0.1% each. The percentage error in measuring its resistance will be: [31 Jan, 2024 (Shift-I)]

(a) 0.2% (b) 0.3% (c) 0.1% (d) 0.144%

89. The resistance $R=\frac{V}{I}$ where $V=(200\pm5)$V and $I=(20\pm0.2)$A, the percentage error in the measurement of R is: [29 Jan, 2024 (Shift-I)]

(a) 3.5% (b) 7% (c) 3% (d) 5.5%

90. A physical quantity Q is found to depend on quantities a, b, c by the relation $Q=\frac{a^4b^3}{c^2}$ The percentage error in a, b and c are 3%, 4% and 5% respectively. Then, the percentage error in Q is: [29 Jan, 2024 (Shift-II)]

(a) 66% (b) 43% (c) 33% (d) 14%

91. A 2 meter long scale with least count of 0.2 cm is used to measure the locations of objects on an optical bench. While measuring the focal length of a convex lens, the object pin and the convex lens are placed at 80 cm mark and 1m mark respectively. The image of the object pin on the other side of lens coincides with image pin that is kept at 180 cm mark. The % error in the estimation of focal length is: [06 Apr, 2023 (Shift-II)]

(a) 1.02 (b) 0.85 (c) 1.70 (d) 0.51

92. A physical quantity P is given as

$$P=\frac{a^2b^3}{c\sqrt{d}}$$

The percentage error in the measurement of a, b, c and d are 1%, 2%, 3% and 4% respectively. The percentage error in the measurement of quantity P will be [10 Apr, 2023 (Shift-I)]

(a) 13% (b) 14% (c) 12% (d) 16%

93. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R

Assertion A: A spherical body of radius (5 ± 0.1) mm having a particular density is falling through a liquid of constant density. The percentage error in the calculation of its terminal velocity is 4%.

Reason R: The terminal velocity of the spherical body falling through the liquid is inversely proportional to its radius.

In the light of the above statements, choose the correct answer from the options given below [13 Apr, 2023 (Shift-II)]

(a) Both A and R are true but R is not the correct explanation of A
(b) Both A and R are true and R is the correct explanation of A
(c) A is false but R is true
(d) A is true but R is false

94. Two resistances are given as $R_1=(10\pm0.5)\Omega$ and $R_2=(15\pm0.5\,\Omega$. The percentage error in the measurement of equivalent resistance when they are connected in parallel is [6 Apr, 2023 (Shift-I)]

(a) 6.33 (b) 2.33
(c) 4.33 (d) 5.33

95. A body of mass (5 ± 0.5) kg is moving with a velocity of (20 ± 0.4) m/s. Its kinetic energy will be [13 Apr, 2023 (Shift-I)]

(a) $(1000\pm140)\,J$ (b) $(1000\pm0.14)\,J$
(c) $(500\pm0.14)\,J$ (d) $(500\pm140)\,J$

96. A cylindrical wire of mass $(0.4\pm0.01)g$ has length (8 ± 0.04) cm and radius (6 ± 0.03) mm. The maximum error in its density will be [08 Apr, 2023 (Shift-I)]

(a) 1% (b) 3.5% (c) 4% (d) 5%

97. If $Z=\frac{A^2B^3}{C^4}$, then the relative error in Z will be: [25 June, 2022 (Shift-I)]

(a) $\frac{\Delta A}{A}+\frac{\Delta B}{B}+\frac{\Delta C}{C}$ (b) $\frac{2\Delta A}{A}+\frac{3\Delta B}{B}-\frac{4\Delta C}{C}$

(c) $\frac{2\Delta A}{A}+\frac{3\Delta B}{B}+\frac{4\Delta C}{C}$ (b) $\frac{\Delta A}{A}+\frac{\Delta B}{B}-\frac{\Delta C}{C}$

98. In an experiment to determine the Young's modulus of wire of a length exactly 1 m, the extension in the length of the wire is measured as 0.4 mm with an uncertainty of ±0.02 mm when a load of 1 kg is applied. The diameter of the wire is measured as 0.4 mm with an uncertainty of ±0.01mm.

The error in the measurement of Young's modulus (ΔY) is found to be $x\times10^{10}$Nm^{-2}. The value of x is _____.

(take g = 10 ms^{-2}) [26 July, 2022 (Shift-I)]

@TAKE_FREE_EXCLUSIVE_ONLINE

99. A torque meter is calibrated to reference standards of mass, length and time each with 5% accuracy. After calibration, the measured torque with this torque meter will have net accuracy of
[27 July, 2022 (Shift-I)]
(a) 15% (b) 25%
(c) 75% (d) 5%

100. A silver wire has a mass (0.6 ± 0.006)g, radius (0.5 ± 0.005)mm and length(4 ± 0.04) cm. The maximum percentage error in the measurement of its density will be: [27 June, 2022 (Shift-I)]
(a) 4% (b) 3% (c) 6% (d) 7%

101. For $z = a^2x^3y^{\frac{1}{2}}$, where '$a$' is a constant. If percentage error in measurement of 'x' and 'y' are 4% and 12% respectively, then the percentage error for 'z' will be _____ %.
[25 June, 2022 (Shift-I)]

102. A student in the laboratory measures thickness of a wire using screw gauge. The readings are 1.22 mm, 1.23 mm, 1.19 mm and 1.20 mm. The percentage error is $\frac{x}{121}$%. The value of x is _____.
[28 June, 2022 (Shift-II)]

103. In experiment to find acceleration due to gravity (g) using simple pendulum, time period of 0.5 s is measured from time of 100 oscillation with a watch of 1 s resolution. If measured value of length is 10 cm known to 1 mm accuracy, The accuracy in the determination of g is found to be x %. The value of x is _____.
[28 July, 2022 (Shift-II)]

104. A student measuring the diameter of a pencil of circular cross-section with the help of a vernier scale records the following four readings 5.50 mm, 5.55 mm, 5.45 mm, and 5.65 mm. The average of these four readings is 5.5375 mm and the standard deviation of the data is 0.07395 mm. The average diameter of the pencil should therefore be recorded as
[6 Sep, 2022 (Shift-II)]
(a) (5.5375 ± 0.0739) mm (b) (5.54 ± 0.07) mm
(c) (5.538 ± 0.074) mm (d) (5.5375 ± 0.0740) mm

105. In order to determine the Young's modulus of a wire of radius 0.2 cm (measured using a scale of least count = 0.001 cm) and length 1m (measured using a scale of least count = 1 mm), a weight of mass 1kg (measured using a scale of least count = 1g) was hanged to get the elongation of 0.5 cm (measured using a scale of least count 0.001 cm). What will be the fractional error in the value of Young's modulus determined by this experiment?
[16 March, 2021 (Shift-II)]
(a) 0.14% (b) 9%
(c) 1.4% (d) 0.9%

106. The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$.
Measured value of 'L' is 1.0 m from meter scale having a minimum division of 1 mm and time of one- complete oscillation is 1.95 s measured from stopwatch of 0.01 s resolution. The percentage error in the determination of 'g' will be: [24 Feb, 2021 (Shift-II)]
(a) 1.33% (b) 1.13%
(c) 1.03% (d) 1.30%

107. In the experiment of Ohm's law, a potential difference applied across the end of a conductor of length 10.0 cm and diameter of 5.00 mm. The measured current in the conductor is 2.00 A. The maximum permissible percentage error in the resistivity of the conductor is: [18 March, 2021 (Shift-I)]
(a) 3.9 (b) 8.4 (c) 3.0 (d) 7.5

108. A wire of 1Ω has a length of 1m. It is stretched till its length increases by 25%. The percentage change in resistance to the nearest integer is: [26 Feb, 2021 (Shift-II)]
(a) 56% (b) 76% (c) 12.5% (d) 25%

109. Three students S_1, S_2 and S_3 perform an experiment for determining the acceleration due to gravity (g) using a simple pendulum. They use different lengths of pendulum and record time for different number of oscillations. The observations are as shown in the table.
[22 July, 2021 (Shift-II)]

Student No.	Length of Pendulum (cm)	No. of oscillations (n)	Total for n Time oscillations	Period (s)
1	64.0	8	128.0	16.0
2	64.0	4	64.0	16.0
3	20.0	4	36.0	9.0

(Least count of length = 0.1 cm,
least count for time = 0.1 s)
If E_1, E_2 and E_3 are the percentage errors 'g' for students 1, 2 and 3 respectively, then the minimum percentage error is obtained by student no._____.

110. If the length of the pendulum in pendulum clock increases by 0.1%, then the error in time per day is [26 Aug, 2021 (Shift-II)]
(a) 8.64 s (b) 43.2 s (c) 86.4 s (d) 4.32 s

111. The time period of a simple pendulum is given by $T = 2\pi\sqrt{\frac{l}{g}}$. The measured value of the length of pendulum is 10 cm known to a l mm accuracy. The time for 200 oscillations of the pendulum is found to be 100 second using a clock of 1 s resolution. The percentage accuracy in the determination of 'g' using this pendulum is 'x'. The value of 'x' to be nearest integer is [18 March, 2021 (Shift-I)]
(a) 2% (b) 3% (c) 5% (d) 4%

112. A physical quantity 'y' is represented by the formula $y = m^2r^{-4}g^x\ell^{-\frac{3}{2}}$ if the percentage errors found in y, m, r, ℓ and g are 18, 1, 0.5, 4 and p respectively, then find the value of x and p.
[27 July, 2021 (Shift-II)]
(a) 5 and ± 2 (b) $\frac{16}{3}$ and $\pm\frac{3}{2}$
(c) 8 and ± 2 (d) 4 and ± 3

113. A student determined Young's Modulus of elasticity using th formula $Y = \frac{MgL^3}{4bd^3\delta}$. The value of g is taken to be 9.8 m/s², withou any significant error, his observation are as follows:
[1 Sept, 2021 (Shift-II

@NEET_JEE_ADVANCE_FOUNDATION

Physical Quantity	Least count of the Equipment used for measurement	Observed value
Mass (M)	1 g	2 kg
Length of bar (L)	1 mm	1 m
Breadth of bar (b)	0.1 mm	4 cm
Thickness of bar (d)	0.01 mm	0.4 cm
Depression (δ)	0.01 mm	5 mm

Then the fractional error in the measurement of Y is:

(a) 0.083 (b) 0.0155 (c) 0.0083 (d) 0.155

114. The acceleration due to gravity is found upto an accuracy of 4% on a planet. The energy supplied to a simple pendulum of known mass 'm' to undertake oscillations of time period T is being estimated. If time period is measured to an accuracy of 3%, the accuracy to which E is known as _____%. **[26 Aug, 2021 (Shift-II)]**

115. The resistance $R = \frac{V}{I}$, where $V = (50 \pm 2)$ V and $I = (20 \pm 0.2)$ A. The percentage error in R is 'x' %. The value of 'x' to the nearest integer is _____. **[16 March, 2021 (Shift-I)]**

116. The radius of a sphere is measured to be (7.50 ± 0.85) cm. Suppose the percentage error in its volume is x. The value of x, to the nearest integer, is _____. **[18 March, 2021 (Shift-II)]**

117. A simple pendulum is being used to determine the value of gravitational acceleration g at a certain place. The length of the pendulum is 25.0 cm and a stop watch with 1s resolution measures the time taken for 40 oscillations to be 50 s. The accuracy in g is: **[8 Jan, 2020 (Shift-II)]**

(a) 4.40% (b) 3.40% (c) 2.40% (d) 5.40%

118. A physical quantity z depends on four observables a, b, c and d, as $\frac{a^2b^3}{\sqrt{c}\,d^3}$. The percentages of error in the measurement of a, b, c and d are 2%, 1.5%, 4% and 2.5% respectively. The percentage of error in z is _____. **[05 Sep, 2020 (Shift-I)]**

(a) 13.5% (b) 14.5% (c) 16.5% (d) 12.25%

119. The density of a solid metal sphere is determined by measuring its mass and its diameter. The maximum error in the density of the sphere is $\left(\frac{x}{100}\right)$%. If the relative errors in measuring the mass and the diameter are 6.0% and 1.5% respectively, the value of x is _____ **[6 Sep, 2020 (Shift-I)]**

(a) 5010 (b) 5100 (c) 1050 (d) 5101

120. In the density measurement of a cube, the mass and edge length are measured as (10.00 ± 0.10) kg and (0.10 ± 0.01)m, respectively. The error in the measurement of density is: **[9 April, 2019 (Shift-I)]**

(a) 0.10 kg/m^3 (b) 0.31 kg/m^3
(c) 0.07 kg/m^3 (d) 0.01 kg/m^3

121. In a simple pendulum experiment for determination of acceleration due to gravity (g), time taken for 20 oscillations is measured by using a watch of 1 second least count. The mean value of time taken comes out to be 30s. The length of pendulum is measured by using a meter scale of least count 1 mm and the value obtained is 55.0 cm. The percentage error in the determination of g is close to: **[8 April, 2019 (Shift-II)]**

(a) 0.7% (b) 3.5% (c) 6.8% (d) 0.2%

122. The diameter and height of a cylinder are measured by a meter scale to be 12.6 ± 0.1 cm and 34.2 ± 0.1 cm respectively. What will be the value of its volume in appropriate significant figures? **[10 Jan, 2019 (Shift-II)]**

(a) 4264 ± 81 cm^3 (b) 4264 ± 81.0 cm^3
(c) 4260 ± 80 cm^3 (d) 4300 ± 80 cm^3

123. A copper wire is stretched to make it 0.5% longer. The percentage change in its electric resistance if its volume remains unchanged is **[9 Jan, 2019 (Shift-I)]**

(a) 2.0% (b) 2.5% (c) 1.0% (d) 0.5%

Measuring Instruments

124. One main scale division of a vernier caliper is equal to m units. If n^{th} division of main scale coincides with $(n+1)^{th}$ division of vernier scale, the least count of the vernier caliper is: **[09 April, 2024 (Shift-I)]**

(a) $\frac{n}{(n+1)}$ (b) $\frac{m}{(n+1)}$ (c) $\frac{1}{(n+1)}$ (d) $\frac{m}{n(n+1)}$

125. There are 100 divisions on the circular scale of a screw gauge of pitch 1 mm. With no measuring quantity in between the jaws, the zero of the circular scale lies 5 divisions below the reference line. The diameter of a wire is then measured using this screw gauge. It is found the 4 linear scale divisions are clearly visible while 60 divisions on circular scale coincide with the reference line. The diameter of the wire is: **[08 April, 2024 (Shift-II)]**

(a) 4.65 mm (b) 4.55 mm
(c) 4.60 mm (d) 3.35 mm

126. Least count of a vernier caliper is $\frac{1}{20N}$ cm. The value of one division on the main scale is 1 mm. Then the number of divisions of main scale that coincide with N divisions of vernier scale is: **[08 April, 2024 (Shift-II)]**

(a) $\left(\frac{2N-1}{20N}\right)$ (b) $\left(\frac{2N-1}{2}\right)$
(c) $(2N-1)$ (d) $\left(\frac{2N-1}{2N}\right)$

127. The diameter of a sphere is measured using a vernier caliper whose 9 divisions of main scale are equal to 10 divisions of vernier scale. The shortest division on the main scale is equal to 1 mm. The main scale reading is 2 cm and second division of vernier scale coincides with a division on main scale. If mass of the sphere is 8.635 g, the density of the sphere is: **[08 April, 2024 (Shift-I)]**

(a) 2.5 g/cm^3 (b) 1.7 g/cm^3
(c) 2.2 g/cm^3 (d) 2.0 g/cm^3

128. In a vernier calliper, when both jaws touch each other, zero of the vernier scale shifts towards left and its 4th division coincides exactly with a certain division on main scale. If 50 vernier scale divisions equal to 49 main scale divisions and zero error in the instrument is 0.04 mm then how many main scale divisions are there in 1 cm? **[06 April, 2024 (Shift-II)]**

(a) 40 (b) 5 (c) 20 (d) 10

@TAKE_CARE_X_@RAJ_EDUNET

129. In finding out refractive index of glass slab the following observations were made through travelling microscope 50 vernier scale division = 49 MSD; 20 divisions on main scale in each cm
[06 April, 2024 (Shift-II)]

For mark on paper
MSR = 8.45 cm, VC = 26
For mark on paper seen through slab
MSR = 7.12 cm, VC = 41
For powder particle on the top surface of the glass slab
MSR = 4.05 cm, VC = 1
(MSR = Main Scale Reading, VC = Vernier Coincidence)
Refractive index of the glass slab is:
(a) 1.42 (b) 1.52 (c) 1.24 (d) 1.35

130. While measuring diameter of wire using screw gauge the following readings were noted. Main scale reading is 1 mm and circular scale reading is equal to 42 divisions. Pitch of screw gauge is 1 mm and it has 100 divisions on circular scale. The diameter of the wire is $\frac{x}{50}$ mm. The value of x is:
[06 April, 2024 (Shift-I)]
(a) 142 (b) 71
(c) 42 (d) 21

131. A vernier callipers has 20 divisions on the vernier scale, which coincides with 19th division on the main scale. The least count of the instrument is 0.1 mm. One main scale division is equal to ____ mm.
[05 April, 2024 (Shift-II)]
(a) 1 (b) 0.5
(c) 2 (d) 5

132. 10 divisions on the main scale of a Vernier calliper coincide with 11 divisions on the Vernier scale. If each division on the main scale is of 5 units, the least count of the instrument is:
[1 Feb, 2024 (Shift-I)]
(a) $\frac{1}{2}$ (b) $\frac{10}{11}$ (c) $\frac{50}{11}$ (d) $\frac{5}{11}$

133. If 50 Vernier divisions are equal to 49 main scale divisions of a travelling microscope and one smallest reading of main scale is 0.5 mm, the Vernier constant of travelling microscope is:
[30 Jan, 2024 (Shift-II)]
(a) 0.1 mm (b) 0.1 cm (c) 0.01 cm (d) 0.01 mm

134. Identify the physical quantity that cannot be measured using spherometer:
[27 Jan, 2024 (Shift-I)]
(a) Radius of curvature of concave surface
(b) Specific rotation of liquids
(c) Thickness of thin plates
(d) Radius of curvature of convex surface

135. Given below are two statements: one is labelled as Assertion(A) and the other is labelled as Reason (R).
Assertion (A): In Vernier calliper if positive zero error exists, then while taking measurements, the reading taken will be more than the actual reading.
Reason (R): The zero error in Vernier Calliper might have happened due to manufacturing defect or due to rough handling.
In the light of the above statements, choose the correct answer from the options given below:
[27 JAN, 2024 (Shift-II)]
(a) Both (A) and (R) are correct and (R) is the correct explanation of (A)
(b) Both (A) and (R) are correct but (R) is not the correct explanation of (A)
(c) (A) is true but (R) is false
(d) (A) is false but (R) is true

136. In an experiment with Vernier callipers of least count 0.1 mm, when two jaws are joined together the zero of Vernier scale lies right to the zero of the main scale and 6th division of Vernier scale coincides with the main scale division. While measuring the diameter of a spherical bob, the zero of vernier scale lies in between 3.2 cm and 3.3 cm marks, and 4th division of vernier scale coincides with the main scale division. The diameter of bob is measured as :
[10 Apr, 2023 (Shift-II)]
(a) 3.18 cm (b) 3.25 cm (c) 3.26 cm (d) 3.22 cm

137. Given below are two statements :
Statements I : Astronomical unit (Au). Parsec (Pc) and Light year (ly) are units for measuring astronomical distances.
Statements II: Au < Parsec (Pc) < ly
In the light of the above statements. Choose the most appropriate answer from the options given below:
[11 Apr, 2023 (Shift-I)]
(a) Both Statements I and Statements II are correct
(b) Statements I is correct but Statements II is incorrect
(c) Both Statements I and Statements II are incorrect
(d) Statements I is incorrect but statements II is correct

138. In a screw gauge, there are 100 divisions on the circular scale and the main scale moves by 0.5 mm on a complete rotation of the circular scale. The zero of circular scale lies 6 divisions below the line of graduation when two studs are brought in contact with each other. When a wire is placed between the studs, 4 linear scale divisions are clearly visible while 46th division the circular scale coincide with the reference line. The diameter of the wire is ____ × 10^{-2} mm.
[30 Jan, 2023 (Shift-I)]

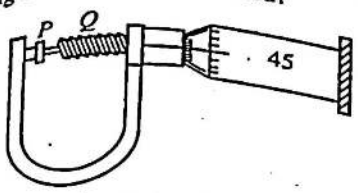
139. In a Vernier Calliper, 10 divisions of Vernier scale is equal to the 9 divisions of main scale. When both jaws of Vernier calipers touch each other, the zero of the Vernier scale is shifted to the left of zero of the main scale and 4th Vernier scale division exactly coincides with the main scale reading. One main scale division is equal to 1 mm. While measuring diameter of a spherical body, the body is held between two jaws. It is now observed that zero of the Vernier scale lies between 30 and 31 divisions of main scale reading and 6th Vernier scale division exactly coincides with the main scale reading. The diameter of the spherical body will be
[26 July, 2022 (Shift-II)]
(a) 3.02 cm (b) 3.06 cm
(c) 3.10 cm (d) 3.20 cm

140. The distance of the Sun from earth is 1.5×10^{11} m and its angular diameter is (2000) s when observed from the earth. The diameter of the Sun will be:
[27 June, 2022 (Shift-II)]
(a) 2.45×10^{10} m (b) 1.45×10^{10} m
(c) 1.45×10^{9} m (d) 0.14×10^{9} m

141. A travelling microscope has 20 divisions per cm on the main scale while its vernier scale has total 50 divisions and 25 vernier scale divisions are equal to 24 main scale divisions, what is the least count of the travelling microscope?
[29 July, 2022 (Shift-I)]
(a) 0.001 cm (b) 0.002 mm
(c) 0.002 cm (d) 0.005 cm

@FAKE_JOSE_X_OFFICIAL

142. In an experiment ... of wire using screw gauge, the following observations were noted?



A. Screw moves 0.5 mm or main scale in one complete rotation.
B. Total divisions on circular scale = 50
C. Main scale reading is 2.5 mm
D. 45th division of circular scale is in the pitch line
Then the diameter of wire is [29 July, 2022 (Shift-I)]
(a) 2.92 mm (b) 2.54 mm (c) 2.98 mm (d) 3.45 mm

143. The Vernier constant of Vernier callipers is 0.1 mm and it has zero error of (–0.05) cm. While measuring diameter of a sphere, the main scale reading is 1.7 cm and coinciding vernier division is 5. The corrected diameter will be _____ $\times 10^{-2}$ cm.
[29 June, 2022 (Shift-II)]

144. The one division of main scale of Vernier callipers reads 1 mm and 10 divisions of Vernier scale is equal to the 9 divisions on main scale. When the two jaws of the instrument touch each other, the zero of the Vernier lies to the right of zero of the main scale and its fourth division coincides with a main scale division. When a spherical bob is tightly placed between the two jaws, the zero of the Vernier scale lies in between 4.1 cm and 4.2 cm and 6th Vernier division coincides with a main scale division. The diameter of the bob will be _____ $\times 10^{-2}$ cm
[27 July, 2022 (Shift-I)]

145. In a vernier callipers, each cm on the main scale is divided into 20 equal parts. If tenth vernier scale division coincides with ninth main scale division. Then the value of vernier contant will be _____ $\times 10^{-2}$ mm.
[26 June, 2022 (Shift-I)]

146. A screw gauge of pitch 0.5 mm is used to measure the diameter of uniform wire of length 6.8cm, the main scale reading is 1.5 mm and circular scale reading is 7. The calculated curved surface area of wire to appropriate significant figures is:
[26 July, 2022 (Shift-I)]
[Screw gauge has 50 divisions on its circular scale]
(a) 6.8 cm^2 (b) 3.4 cm^2
(c) 3.9 cm^2 (d) 2.4 cm^2

147. In a Screw Gauge, fifth division of the circular scale coincides with the reference line when the ratchet is closed. There are 50 divisions on the circular scale, and the main scale moves by 0.5 mm on a complete rotation. For a particular observation the reading on the main scale is 5mm and the 20th division of the circular scale coincides with reference line. Calculate the true reading.
[26 Aug, 2021 (Shift-I)]
(a) 5.25 mm (b) 5.15 mm
(c) 5.20 mm (d) 5.00 mm

148. The vernier scale used for measurement has a positive zero error of 0.2 mm. If while taking a measurement it was noted that zero on the vernier scale lies between 8.5 cm and 8.6 cm. and vernier coincidence is 6, then the correct value of measurement is _____
(least count = 0.01 cm) [17 March, 2021 (Shift-I)]
(a) 8.58 cm (b) 8.54 cm
(c) 8.56 cm (d) 8.36 cm

149. Suppose you have taken a dilute solution of oleic acid in such a way that its concentration becomes 0.01 cm^3 of oleic acid per cm^3 of the solution. Then you make a thin film of this solution (monomolecular thickness) of area 4 cm^2 by considering 100 spherical drops of radius $\left(\frac{3}{40\pi}\right)^{\frac{1}{3}} \times 10^{-3}$ cm. Then the thickness of oleic acid Layer will be $x \times 10^{-14}$ m. Where x is _____. [17 March, 2021 (Shift-II)]

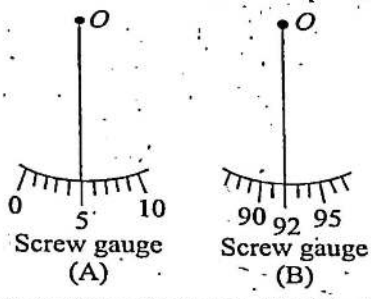
150. The pitch of the screw gauge is 1 mm and there are 100 divisions on the circular scale. When nothing is put in between the jaws, the zero of the circular scale lies 8 divisions below the reference line. When a wire is placed between the jaws, the first linear scale division is clearly visible while 72nd division on circular scale coincides with the reference line, The radius of the wire is:
[25 Feb, 2021 (Shift-I)]
(a) 0.82 mm (b) 1.64 mm (c) 0.90 mm (d) 1.80 mm

151. Assertion A: If in five complete rotations of the circular scale, the distance travelled on main scale of the screw gauge is 5 mm and there are 50 total divisions on circular scale, then least count is 0.001 cm.
Reason R: Least Count $= \frac{\text{Pitch}}{\text{Total divisions on circular scle}}$
In the light of the above statement, choose the most appropriate answer from the options given below: [27 July, 2021 (Shift-I)]
(a) A is correct but R is not correct.
(b) A is not correct but R is correct.
(c) Both A and R are correct and R is NOT the correct explanation of A.
(d) Both A and R are correct and R is the correct explanation of A.

152. One main scale division of a vernier calipers is 'a' cm and n^{th} division of the vernier scale coincide with $(n-1)^{th}$ division of the main scale. The least count of the calipers (in mm) is
[16 March, 2021 (Shift-I)]
(a) $\frac{10na}{n-1}$ (b) $\frac{10a}{n-1}$ (c) $\frac{10a}{n}$ (d) $\left(\frac{n-1}{10n}\right)a$

153. The diameter of a spherical bob is measured using a vernier callipers. 9 divisions of the main scale, in the vernier callipers, are equal to 10 divisions of vernier scale. One main scale division is 1 mm. The main scale reading is 10 mm and 8th division of vernier scale was found to coincide exactly with one of the main scale division. If the given vernier callipers has positive zero error of 0.04 cm, then the radius of the bob is _____ $\times 10^{-2}$ cm. [31 Aug, 2021 (Shift-II)]

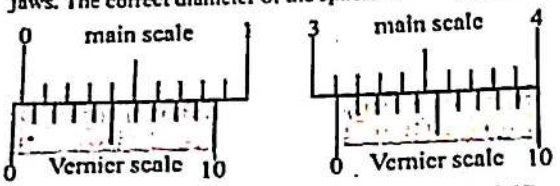
154. Student A and Student B used two screw gauges of equal pitch and 100 equal circular divisions to measure the radius of a given wire. The actual value of the radius of the wire is 0.322 cm. The absolute value of the difference between the final circular scale readings observed by the students A and B is _____.
[25 July, 2021 (Shift-I)]



[Figure shows position of reference 'O' when jaws of screw gauge are closed] Given pitch = 0.1 cm.

©AKASH CBSE EXAMINATION NET

155. The smallest division on the main scale of a Vernier callipers is 0.1 cm. Ten divisions of the Vernier scale correspond to nine divisions of the main scale. The figure below on the left shows the reading of this calliper with no gap between its two jaws. The figure on the right shows the reading with a solid sphere held between the jaws. The correct diameter of the sphere is [JEE Adv, 2021]



(a) 3.07 cm (b) 3.11 cm (c) 3.15 cm (d) 3.17 cm

156. A screw gauge has 50 divisions on its circular scale. The circular scale is 4 units ahead of the pitch scale marking, prior to use. Upon one complete rotation of the circular scale, a displacement of 0.5 mm is noticed on the pitch scale. The nature of zero error involved, and the least count of the screw gauge, are respectively: [6 Sep, 2020 (Shift-I)]

(a) Negative, 2μm
(b) Positive, 10μm
(c) Positive, 0.1 mm
(d) Positive, 0.1 μm

157. For the four sets of three measured physical quantities as given below. Which of the following options is correct? [9 Jan, 2020 (Shift-II)]

(i) $A_1 = 24.36, B_1 = 0.0724, C_1 = 256.2$
(ii) $A_2 = 24.44, B_2 = 16.082, C_2 = 240.2$
(iii) $A_3 = 25.2, B_3 = 19.2812, C_3 = 236.183$
(iv) $A_4 = 25, B_4 = 236.191, C_4 = 19.5$

(a) $A_4+B_4+C_4 < A_1+B_1+C_1 = A_2+B_2+C_2 = A_3+B_3+C_3$
(b) $A_1+B_1+C_1 < A_3+B_3+C_3 < A_2+B_2+C_2 < A_4+B_4+C_4$
(c) $A_1+B_1+C_1 = A_2+B_2+C_2 = A_3+B_3+C_3 = A_4+B_4+C_4$
(d) $A_4+B_4+C_4 < A_1+B_1+C_1 < A_3+B_3+C_3 < A_2+B_2+C_2$

158. Using screw gauge of pitch 0.1 cm and 50 divisions on its circular scale, the thickness of an object is measured. It should correctly be recorded as [3 Sep, 2020 (Shift-I)]

(a) 2.121 cm (b) 2.123 cm (c) 2.124 cm (d) 2.125 cm

159. The least count of the main scale of a screw gauge is 1 mm. The minimum number of divisions on its circular scale required to measure 5 μm diameter of a wire is [12 Jan, 2019 (Shift-I)]

(a) 50 (b) 200
(c) 100 (d) 500

JEE-Advanced

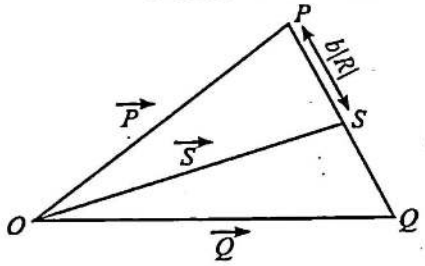
Units, System of Units

Single Correct

1. Consider an expanding sphere of instantaneous radius R whose total mass remains constant. The expansion is such that the instantaneous density ρ remains uniform throughout the volume. The rate of fractional change in density $\left(\frac{1}{\rho}\frac{d\rho}{dt}\right)$ is constant. The velocity v of any point of the surface of the expanding sphere is proportional to C-26.78 W-30.86 UA-42.37 (JEE Adv. 2017)

(a) R (b) $\frac{1}{R}$ (c) R^3 (d) $R^{\frac{2}{3}}$

2. Three vectors $\vec{P}$, $\vec{Q}$ and $\vec{R}$ are shown in the figure. Let S be any point on the vector $\vec{R}$. The distance between the points P and S is $b|\vec{R}|$. The general relation among vectors $\vec{P}$, $\vec{Q}$ and $\vec{S}$ is C-46.13 W-17.08 UA-36.79 (JEE Adv. 2017)



$\vec{R} = \vec{Q} - \vec{P}$

(a) $\vec{S} = (1-b^2)\vec{P} + b\vec{Q}$
(b) $\vec{S} = (b-1)\vec{P} + b\vec{Q}$
(c) $\vec{S} = (1-b)\vec{P} + b\vec{Q}$
(d) $\vec{S} = (1-b)\vec{P} + b^2\vec{Q}$

3. A cube has a side of length 1.2×10^{-2} m. Calculate its volume. (IIT-JEE 2003)

(a) 1.7×10^{-6} m^3 (b) 1.73×10^{-6} m^3
(c) 1.70×10^{-6} m^3 (d) 1.732×10^{-6} m^3

Subjective

4. Write the dimensions of the following in terms of mass, time, length and charge. (IIT-JEE 1982)

A. Magnetic flux B. Rigidity modulus

5. Give the MKS units for each of the following quantities. (IIT-JEE 1980)

1. Young's modulus 2. Magnetic induction
3. Power of a lens

Multiple Correct

6. A physical quantity $\vec{S}$ is defined as $\vec{S} = (\vec{E} \times \vec{B})/\mu_0$, where $\vec{E}$ is electric field, $\vec{B}$ is magnetic field and μ_0 is the permeability of free space. The dimensions of $\vec{S}$ are the same as the dimensions of which of the following quantity (ies)? C-40.2 W-27.78 UA-22.17 PC-9.84 (JEE Adv. 2021)

@FAKE_CODE X @RAJEDUNET

(a) $\frac{\text{Energy}}{\text{Charge} \times \text{Current}}$ (b) $\frac{\text{Force}}{\text{Length} \times \text{Time}}$

(c) $\frac{\text{Energy}}{\text{Volume}}$ (d) $\frac{\text{Power}}{\text{Area}}$

7. The SI unit of the inductance, the henry can by written as (IIT-JEE 1998)

(a) weber/ampere (b) volt-second/ampere

(c) joule/(ampere)^2 (d) ohm-second

Match the Column

8. Some physical quantities are given in Column-I and some possible SI units in which these quantities may be expressed are given in Column-II. Match the physical quantities in Column-I with the units in Column-II. (IIT-JEE 2007)

	Column-I		Column-II
A.	GM_eM_sG - universal gravitational constant, M_e - mass of the earth, M_s - mass of the sun,	p.	(volt) (coulomb) (meter)
B.	$\frac{3RT}{M}$ R - universal gas constant, T - absolute temperature, M - molar mass,	q.	(kilogram) (meter)^2 (second)$^{-2}$
C.	$\frac{F^2}{q^2B^2}$ F - force, q - charge, B - magnetic field,	r.	(meter)^2 (second)$^{-2}$
D.	$\frac{GM_e}{R_e}$ G - universal gravitational constant, M_e - mass of the earth, R_e - radius of the earth,	s.	(farad) (volt)^2 (kg)$^{-1}$

9. Column-I gives three physical quantities. Select the appropriate units for the choices given in Column-II. Some of the physical quantities may have more than one choice. (IIT-JEE 1990)

Column-I	Column-II
Capacitance	ohm-second
Inductance	Coulomb^2 joule^{-1}
Magnetic induction	Coulomb (volt)$^{-1}$
	Newton (ampere metre)$^{-1}$
	volt-second (ampere)$^{-1}$

Fill in the Blanks

10. Two vectors $\vec{A}$ and $\vec{B}$ are defined as $\vec{A} = a\hat{i}$ and $\vec{B} = a(\cos \omega t \hat{i} + \sin \omega t \hat{j})$, where a is a constant and $\omega = \pi/6$ rad s^{-1}. If $|\vec{A} + \vec{B}| = \sqrt{3}\,|\vec{A} - \vec{B}|$ at time $t = \tau$ for the first time, the value of τ, in seconds, is ..... . C-35.57 W-49.68 UA-14.75 (JEE Adv.2018)

Dimension, Finding Dimensional Formula

Single Correct

11. Which of the following sets have different dimensions? (IIT-JEE 2005)

(a) Pressure, Young's modulus, Stress

(b) Emf, Potential difference, Electric potential

(c) Heat, Work done, Energy

(d) Dipole moment, Electric flux, Electric field

12. In the relation, $p = \frac{\alpha}{\beta} e^{-\left(\frac{\alpha z}{k\theta}\right)}$ is pressure, z is distance, k is Boltzmann's constant and θ is the temperature. The dimensional formula of β will be (IIT-JEE 2004)

(a) $[M^0L^2T^0]$ (b) $[ML^2T]$ (c) $[ML^0T^{-1}]$ (d) $[M^0L^2T^{-1}]$

13. A quantity X is given by $\varepsilon_0 L \frac{\Delta V}{\Delta t}$, where ε_0 is the permittivity of free space, L is a length, ΔV is a potential difference and Δt is a time interval. The dimensional formula for X is the same as that of (IIT-JEE 2001)

(a) Resistance (b) Charge (c) Voltage (d) Current

14. The dimensions of $\frac{1}{2}\varepsilon_0 E^2$ (ε_0 : permittivity of free space; E : electric field) is: (IIT-JEE 2001)

(a) $[MLT]$ (b) $[ML^2T^{-2}]$ (c) $[ML^{-1}T^{-2}]$ (d) $[ML^2T^{-1}]$

15. Let $[\varepsilon_0]$ denote the dimensional formula of the permittivity of vacuum. If M = mass, L = length, T = Time and A = electric current, then (IIT-JEE 1998)

(a) $[\varepsilon_0] = [M^{-1}L^{-3}T^2A]$ (b) $[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2]$

(c) $[\varepsilon_0] = [M^{-2}L^2T^{-1}A^{-2}]$ (d) $[\varepsilon_0] = [M^{-1}L^2T^{-1}A^2]$

Multiple Correct

16. A length-scale (l) depends on the permittivity (ε) of a dielectric material, Boltzmann's constant (k_B), the absolute temperature (T), the number per unit volume (n) of certain charged particles and the charge (q) carried by each of the particles. Which of the following expression(s) for l is (are) dimensionally correct?

C-17.85 W-20.89 UA-49.13 PC-12.13 (JEE Adv. 2016)

(a) $l = \sqrt{\left(\frac{nq^2}{\varepsilon k_B T}\right)}$ (b) $l = \sqrt{\left(\frac{Ek_BT}{nq^2}\right)}$

(c) $l = \sqrt{\left(\frac{q^2}{\varepsilon h^{2/3} k_B T}\right)}$ (d) $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{1/3} k_B T}\right)}$

17. Planck's constant h, speed of light c and gravitational constant G are used to form a unit of length L and a unit of mass M. Then, the correct options is/are (JEE Adv. 2015)

(a) $M \propto \sqrt{c}$ (b) $M \propto \sqrt{G}$

(c) $L \propto \sqrt{h}$ (d) $L \propto \sqrt{G}$

SHAKE-IT-X@RAJEEV

18. In terms of potential difference V, electric current I, permittivity ε_0, permeability μ_0 and speed of light c the dimensionally correct equations is/are (JEE Adv. 2015)

(a) $\mu_0 I^2 = \varepsilon_0 V^2$ (b) $\varepsilon_0 I = \mu_0 V^2$

(c) $I = \varepsilon_0 c V$ (d) $\mu_0 c I = \varepsilon_0 V^2$

19. Let $[\varepsilon_0]$ denote the dimensional formula of the permittivity of the vacuum. If M = mass, L = length, T = time and I = electric current. Then. (IIT-JEE1998)

(a) $[\varepsilon_0] = [M^{-1}L^{-3}T^2A]$ (b) $[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2]$

(c) $[\mu_0] = [MLT^{-2}A^{-2}]$ (d) $[\mu_0] = [ML^2T^{-1}]$

20. The pairs of physical quantities that have the same dimensions is (are) (IIT-JEE 1995)

(a) Reynolds number and coefficient of friction

(b) Curie and frequency of a light wave

(c) Latent heat and gravitational potential

(d) Planck's constant and torque

21. The dimensions of the quantities in one (or more) of the following pairs are the same. Identify the pair (s). (IIT-JEE 1986)

(a) Torque and work

(b) Angular momentum and work

(c) Energy and Young's modulus

(d) Light year and wavelength

22. L, C and R represent the physical quantities inductance, capacitance and resistance, respectively. The combinations which have the dimensions of frequency are (IIT-JEE 1984)

(a) $\frac{1}{RC}$ (b) $\frac{R}{L}$ (c) $\frac{1}{\sqrt{LC}}$ (d) $\frac{C}{L}$

Match the Column

23. Match the physical quantities given in Column-I with dimensions expressed in terms of mass (M), length (L), time (T) and charge (Q) given in Column-II and write the correct answer against the matched quantity in a tabular form in your answer book. (IIT-JEE 1990)

Column-I		Column-II	
A.	Angular momentum	p.	$[ML^2T^{-2}]$
B.	Latent heat	q.	$[ML^2Q^{-2}]$
C.	Torque	r.	$[ML^2T^{-1}]$
D.	Capacitance	s.	$[M^{-1}L^{-2}T^2Q^2]$
E.	Inductance	t.	$[M^{-1}L^{-2}T^2Q^2]$
F.	Resistivity	u.	$[L^2T^{-2}]$

Subjective

24. Planck's constant has dimensions: (IIT-JEE 1985)

Fill in the Blanks

25. The equation of state of a real gas is given by (IIT-JEE 1997)

$$\left(p+\frac{a}{V^2}\right)(V-b)=RT$$

where p, V and T are pressure, volume and temperature, respectively and R is the universal gas constant. The dimensions of the constant a in the above equation is.....

Principle of Homogeneity of Dimension

Subjective

26. A gas bubble, from an explosion under water, oscillates with a period T proportional to $p^a d^b E^c$, where p is the static pressure, d is the density of water and E is the total energy of the explosion. Find the values of a, b and c. (IIT-JEE 1981)

Application of Dimensional Analysis

Single Correct

27. Young's modulus of elasticity Y is expressed in terms of three derived quantities, namely, the gravitational constant G, Planck's constant h and the speed of light c, as $Y = c^\alpha h^\beta G^\gamma$. Which of the following is the correct option? C-60.51 W-20.88 UA-18.62 (JEE Adv. 2023)

(a) $\alpha = 7, \beta = -1, \gamma = -2$ (b) $\alpha = -7, \beta = -1, \gamma = -2$

(c) $\alpha = 7, \beta = -1, \gamma = 2$ (d) $\alpha = -7, \beta = 1, \gamma = -2$

Comprehension Based/Passage Based

Paragraph (Q.28-29): In electromagnetic theory, the electric and magnetic phenomena are related to each other. Therefore, the dimensions of electric and magnetic quantities must also be related to each other. In the questions below, $[E]$ and $[B]$ stand for dimensions of electric and magnetic fields respectively, while $[\varepsilon_0]$ and $[\mu_0]$ stand for dimensions of the permittivity and permeability of free space, respectively. $[L]$ and $[T]$ are dimensions of length and time, respectively. All the quantities are given in SI units. (There are two questions based on PARAGRAPH "X", the question given below is one of them)

28. The relation between $[E]$ and $[B]$ is C-64.34 W-23.48 UA-12.18 (JEE Adv. 2018)

(a) $[E] = [B][L][T]$ (b) $[E] = [B][L]^{-1}[T]$

(c) $[E] = [B][L][T]^{-1}$ (d) $[E] = [B][L]^{-1}[T]^{-1}$

29. The relation between $[\varepsilon_0]$ and $[\mu_0]$ is (JEE Adv. 2018)

(a) $[\mu_0] = [\varepsilon_0][L]^2[T]^{-2}$ (b) $[\mu_0] = [\varepsilon_0][L]^{-2}[T]^2$

(c) $[\mu_0] = [\varepsilon_0]^{-1}[L]^2[T]^{-2}$ (d) $[\mu_0] = [\varepsilon_0]^{-1}[L]^{-2}[T]^2$

Paragraph (Q. 30-31): A dense collection of equal number of electron and positive ions is called neutral plasma. Certain solids containing fixed positive ions surrounded by free electrons can be treated as neutral plasma. Let N be the number density of free electrons, each of mass m. When the electrons are subjected to an electric field, they are displaced relatively away from the heavy positive ions. If the electric field becomes zero, the electrons begin to oscillate about the positive ions with a natural angular frequency ω_p, which is called the plasma frequency.

To sustain the oscillations, a time varying electric field needs to be applied that has an angular frequency ω, where a part of the energy is absorbed and a part of it is reflected. As ω approaches ω_p, all the free electrons are set to resonance together and all the energy is reflected. This is the explanation of high reflectivity of metals.

BEAKER BY CORE EDUNEET

30. Taking the electronic charge as e and the permittivity as ε_0, use dimensional analysis to determine the correct expression for ω_p. **(IIT-JEE 2011)**

(a) $\sqrt{\frac{Ne}{m\varepsilon_0}}$ (b) $\sqrt{\frac{m\varepsilon_0}{Ne}}$

(c) $\sqrt{\frac{Ne^2}{m\varepsilon_0}}$ (d) $\sqrt{\frac{m\varepsilon_0}{Ne^2}}$

31. Estimate the wavelength at which plasma reflection will occur for a metal having the density of electrons $N = 4 \times 10^{27}$ m^{-3}. Take $\varepsilon_0 = 10^{-11}$ and $m = 10^{-30}$, where these quantities are in proper SI units **(IIT-JEE 2011)**

(a) 800 nm (b) 600 nm

(c) 300 nm (d) 200 nm

Multiple Correct

32. Sometimes it is convenient to construct a system of units so that all quantities can be expressed in terms of only one physical quantity. In one such system, dimensions of different quantities are given in terms of a quantity X as follows: [position] = $[X^\alpha]$; [speed] = $[X^\beta]$; [acceleration] = $[X^p]$; [linear momentum] = $[X^q]$; [force] = $[X^r]$. Then **C-45.21 W-20.85 UA-20.46 PC-13.47 (JEE Adv. 2020)**

(a) $\alpha + p = 2\beta$ (b) $p + q - r = \beta$

(c) $p - q + r = \alpha$ (c) $p + q + r = \beta$

33. Let us consider a system of units in which mass and angular momentum are dimensionless. If length has dimension of L, which of the following statement(s) is/are correct? **C-36, W-12, UA-14, PC-38 (JEE Adv, 2019)**

(a) The dimension of force is L^{-3}.

(b) The dimension of energy of L^{-2}.

(c) The dimension of power is L^{-5}.

(d) The dimension of linear momentum is L^{-1}.

Numerical Types/Integer Types

34. To find the distance d over which a signal can be seen clearly in foggy conditions, a railway engineer uses dimensional analysis and assumes that the distance depends on the mass density ρ of the fog, intensity (power/area) S of the light from the signal and its frequency f. The engineer finds that d is proportional to $S^{1/n}$. The value of n is **C-34 W-57.91 UA-8.09 (JEE Adv. 2014)**

Fill in the Blanks

35. In a particular system of units, a physical quantity can be expressed in terms of the electric charge e, electron mass m_e, Planck's constant h, and coulomb's constant $k = \frac{1}{4\pi\varepsilon_0}$, where ε_0 is the permittivity of vacuum. In terms of these physical constants, the dimension of the magnetic field is $[B] = [e^\alpha [m_e]^\beta [h]^\gamma [k]^\delta$. The value of $\alpha + \beta + \gamma + \delta$ is _____. **C-14.97 W-28.88 UA-56.15 (JEE Adv. 2022)**

Errors in Measurement

Single Correct

36. A person measures the depth of a well by measuring the time interval between dropping a stone and receiving the sound of impact with the bottom of the well. The error in his measurement of time is $\delta T = 0.01$s and he measures the depth of the well to be $L = 20$ m. Take the acceleration due to gravity $g = 10$ ms^{-2} and the velocity of sound is 300 ms^{-1}. Then the fractional error in the measurement $\frac{\delta L}{L}$ is closest to **C-17.92 W-40 UA-42.08 (JEE Adv. 2017)**

(a) 1% (b) 5% (c) 3% (d) 0.2%

37. The current voltage relation of diode is given by $I = (e^{1000V/T} - 1)$ mA, where the applied voltage V is in volt and the temperature T is in kelvin. If a student makes an error measuring ±0.01 V while measuring the current of 5 mA at 300 K, what will be the error in the value of current in mA? **(JEE Adv. 2014)**

(a) 0.2 mA (b) 0.02 mA (c) 0.5 mA (d) 0.05 mA

38. In the determination of Young's modulus $\left(Y = \frac{4.MLg}{\pi ld^2}\right)$ by using Searle's method, a wire of length L = 2 m and diameter $d = 0.5$ mm is used. For a load $M = 2.5$ kg, an extension $l = 0.25$ mm in the length of the wire is observed. Quantities d and l are measured using a screw gauge and a micrometer, respectively. They have the same pitch of 0.5 mm. The number of divisions on their circular scale is 100. The contributions to the maximum probable error of the Y measurement is **C-10.96 W-38.26 UA-50.78 (IIT-JEE 2012)**

(a) Due to the errors in the measurements of d and l are the same

(b) Due to the error in the measurement of d is twice that due to the error in the measurement of l

(c) Due to the error in the measurement of l is twice that due to the error in the measurement of d

(d) Due to the error in the measurement of d is four times that due to the error in the measurement of I

39. The density of a solid ball is to be determined in an experiment. The diameter of the ball is measured with a screw gauge, whose pitch is 0.5 mm and there are 50 divisions on the circular scale. The reading on the main scale is 2.5 mm and that on the circular scale is 20 divisions. If the measured mass of the ball has a relative error of 2%, the relative percentage error in the density is **(IIT-JEE 2011)**

(a) 0.9% (b) 2.4% (c) 3.1% (d) 4.4%

40. A student uses a simple pendulum of exactly 1 m length to determine g, the acceleration due to gravity. He uses a stop watch with the least count of 1s for this and records 40s for 20 oscillations. For this observation, which of the following statement(s) is/are true? **(IIT-JEE 2010)**

(a) Error ΔT in measuring T, the time period, is 0.05s

(b) Error ΔT in measuring T, the time period, is 1s

(c) Percentage error in the determination of g is 5%

(d) Percentage error in the determination of g is 2.5%

@FAKE_CBSE_X_@PANEDUNIT

41. A student performs an experiment to determine the Young's modulus of a wire, exactly 2 m long, by Searle's method. In a particular reading, the student measures the extension in the length of the wire to be 0.8 mm with an uncertainty of ±0.05 mm at a load of exactly 1.0 kg. The student also measures the diameter of the wire to be 0.4 mm with an uncertainty of ±0.01 mm. Take $g = 9.8$ m/s² (exact). The Young's modulus obtained from the reading is close to **(IIT-JEE 2007)**

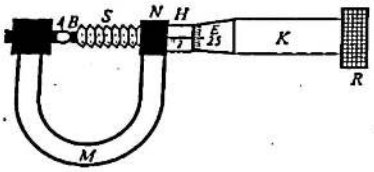
(a) $(2.0 \pm 0.3) \times 10^{11}$ N/m²

(b) $(2.0 \pm 0.2) \times 10^{11}$ N/m²

(c) $(2.0 \pm 0.1) \times 10^{11}$ N/m²

(d) $(2.0 \pm 0.05) \times 10^{11}$ N/m²

42. The circular scale of a screw gauge has 50 divisions and pitch of 0.5 mm. Find the diameter of the sphere. Main scale reading is 2. **(IIT-JEE 2006)**



(a) 1.2 mm (b) 1.25 mm (c) 2.20 mm (d) 2.25 mm

43. A wire has a mass (0.3 ± 0.003) g, radius (0.5 ± 0.005) mm and length (6 ± 0.06) cm. The maximum percentage error in the measurement of its density is **(IIT-JEE 2004)**

(a) 1 (b) 2 (c) 3 (d) 4

Comprehension Based/Passage Based

Paragraph (Q. 44-45): If the measurement errors in all the independent quantities are known, then it is possible to determine the error in any dependent quantity. This is done by the use of series expansion and truncating the expansion at the first power of the error. For example, consider the relation $z = x/y$. If the errors in x, y and z are Δx, Δy and, Δz respectively, then

$$z \pm \Delta z = \frac{x \pm \Delta x}{y \pm \Delta y} = \frac{x}{y}\left(1 \pm \frac{\Delta x}{x}\right)\left(1 \pm \frac{\Delta y}{y}\right)^{-1}$$

The series expansion for $\left(1 \pm \frac{\Delta y}{y}\right)^{-1}$, to first power in $\Delta y/y$, is $1 \mp (\Delta y/y)$. The relative errors in independent variables are always added. So the error in z will be $\Delta z = z\left(\frac{\Delta x}{x} + \frac{\Delta y}{y}\right)$. The above derivation makes the assumption that $\Delta x/x << 1$, $\Delta y/y << 1$. Therefore, the higher powers of these quantities are neglected. **(JEE Adv. 2018)**

44. Consider the ratio $r = \frac{(1-a)}{(1+a)}$ to be determined by measuring a dimensionless quantity a. If the error in the measurement of a is Δa ($\Delta a/a << 1$), then what is the error Δr in determining r?

C-34.7 W-33.81 UA-31.49 (JEE Adv. 2018)

(a) $\frac{\Delta a}{(1+a)^2}$ (b) $\frac{-2\Delta a}{(1+a)^2}$ (c) $\frac{2\Delta a}{(1-a)^2}$ (d) $\frac{2a\Delta a}{(1-a^2)}$

45. In an experiment, the initial number of radioactive nuclei is 3000. It is found that 1000 ± 40 nuclei decayed in the first 10s. For $|x| < 1$, $\ln(1+x) = x$ up to first power in x. The error $\Delta\lambda$, in the determination of the decay constant λ in s^{-1}, is

C-13.32 W-38.29 UA-48.39 (JEE Adv. 2018)

(a) 0.04 (b) 0.03

(c) 0.02 (d) 0.01

Subjective

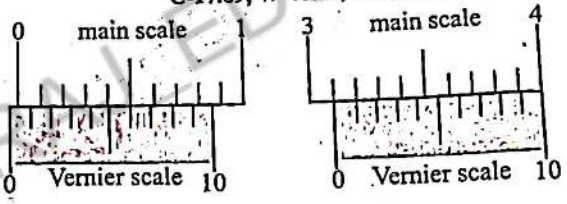
46. The energy of a system as a function of time t is given as $E(t) = A^2 \exp(-\alpha t)$, where $\alpha = 0.2 s^{-1}$. The measurement of A has an error of 1.25%. If the error in the measurement of time is 1.50%, the percentage error in the value of $E(t)$ at $t = 5$s is **(JEE Adv. 2015)**

Measuring Instruments

Single Correct

47. The smallest division on the main scale of a Vernier calipers is 0.1 cm. Ten divisions of the Vernier scale correspond to nine divisions of the main scale. The figure below on the left shows the reading of this caliper with no gap between its two jaws. The figure on the right shows the reading with a solid sphere held between the jaws. The correct diameter of the sphere is

C-17.89, W-46.36, UA-35.75 (JEE Adv. 2021)



(a) 3.07 cm (b) 3.11 cm

(c) 3.15 cm (d) 3.17 cm

48. A steel wire of diameter 0.5 mm and Young's modulus 2×10^{11} Nm^{-2} carries a load of mass m. The length of the wire with the load is 1.0 m. A vernier scale with 10 divisions is attached to the end of this wire. Next to the steel wire is a reference wire to which a main scale, of least count 1.0 mm, is attached. The 10 divisions of the vernier scale correspond to 9 divisions of the main scale. Initially, the zero of vernier scale coincides with the zero of main scale. If the load on the steel wire is increased by 1.2 kg, the vernier scale division which coincides with a main scale division is ($g = 10$ ms^{-2} and $\pi = 3.2$).

C-10.09 W-63.21 UA-26.7 (JEE Adv. 2018)

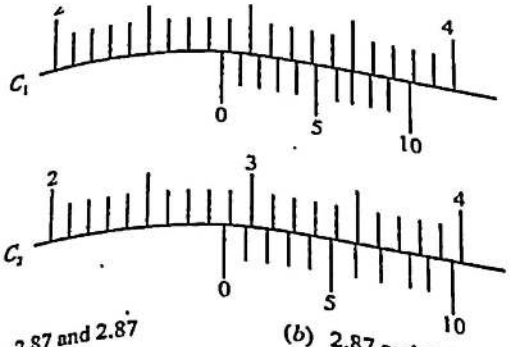
(a) 1 (b) 3

(c) 2 (d) 4

49. There are two vernier calipers both of which have 1 cm divided into 10 equal divisions on the main scale. The vernier scale of one of the calipers (C_1) has 10 equal divisions that correspond to 9 main scale divisions. The vernier scale of the other caliper (C_2) has 10 equal divisions that correspond to 11 main scale divisions. The readings of the two calipers are shown in the figure. The measured values (in cm) by calipers C_1 and C_2 respectively, are

C-28.16 W-43.44 UA-28.4 (JEE Adv. 20

@FAKE_CBSE_X@ENLEDUN



(a) 2.87 and 2.87 (b) 2.87 and 2.83
(c) 2.85 and 2.82 (d) 2.87 and 2.86

50. The diameter of a cylinder is measured using a vernier calipers with no zero error. It is found that the zero of the vernier scale lies between 5.10 cm and 5.15 cm of the main scale. The vernier scale has 50 division equivalent to 2.45 cm. The 24th division of the vernier scale exactly coincides with one of the main scale divisions. The diameter of the cylinder is

C-36.72 W-54.07 UA-9.21 (JEE Adv. 2013)

(a) 5.112 cm (b) 5.124 cm (c) 5.136 cm (d) 5.148 cm

51. A vernier calipers has 1 mm marks on the main scale. It has 20 equal divisions on the vernier scale which match with 16 main scale divisions. For this vernier calipers, the least count is

(IIT-JEE 2010)

(a) 0.02 mm (b) 0.05 mm
(c) 0.1 mm (d) 0.2 mm

52. Students I, II and III perform an experiment for measuring the acceleration due to gravity (g) using a simple pendulum. They use different lengths of the pendulum and/or record time for different number of oscillations. The observations are shown in the table.
Least count for length = 0.1 cm. Least count for time = 0.1s

Student	Length of the pendulum	Number of Oscillations (n)	Total time for (n) Oscillation (cm)	Time(s)
I	64.0	8	128.0	16.0
II	64.0	4	64.0	16.0
III	20.0	4	36.0	9.0

If E_1, E_{11} and E_{II} are the percentage errors in g i.e., $\left(\frac{\Delta_g}{g}\times 100\right)$ for students I, II and III, respectively **(IIT-JEE 2008)**

(a) $E_I = 0$ (b) E_1 is minimum
(c) $E_1 = E_2$ (d) E_3 is maximum

Multiple Correct

53. Consider a vernier caliper in which each 1 cm on the main scale is divided into 8 equal divisions and a screw gauge with 100 divisions on its circular scale. In the vernier calipers, 5 divisions of the vernier scale coincide with 4 divisions on the main scale and in the screw gauge, one complete rotation of the circular scale moves it by two divisions on the linear scale. Then **(JEE Adv. 2015)**

(a) If the pitch of the screw gauge is twice the least count of the vernier caliper, the least count of the screw gauge is 0.01 mm
(b) If the pitch of the screw gauge is twice the least count of the Vernier caliper, the least count of the screw gauge is 0.05 mm
(c) If the least count of the linear scale of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.01 mm
(d) If the least count of the linear scale of the screw gauge is twice the least count of the vernier caliper, the least count of the screw gauge is 0.005 mm

Numerical Types/Integer Types

54. During Searle's experiment, zero of the vernier scale lies between 3.20×10^{-2} m and 3.25×10^{-2} m of the main scale. The 20th division of the vernier scale exactly coincides with one of the main scale divisions. When an additional load of 2 kg is applied to the wire, the zero of the vernier scale still lies between 3.20×10^{-2} m and 3.25×10^{-2} m of the main scale but now the 45th division of vernier scale coincides with one of the main scale divisions. The length of the thin metallic wire is 2 m and its cross-sectional area is 8×10^{-7} m^2. The least count of the vernier scale is 1.0×10^{-5} m. The maximum percentage error in the Young's modulus of the wire is

C-16.38 W-67.42 UA-16.2 (JEE Adv. 2014)

55. The edge of a cube is measured using a vernier caliper. (9 divisions of the main scale is equal to 10 divisions of vernier scale and 1 main scale division is 1 mm). The main scale division reading is 10 and 1 division of vernier scale was found to be coinciding with the main scale. The mass of the cube is 2.736 g. Calculate the density in g/cm^3 upto correct significant figures. **(IIT-JEE 2005)**

56. The pitch of a screw gauge is 1 mm and there are 100 divisions on the circular scale. While measuring the diameter of a wire, the linear scale reads 1 mm and 47th division on the circular scale coincides with the reference line. The length of the wire is 5.6 cm. Find the curved surface area (in cm^2) of the wire in appropriate number of significant figures **(IIT-JEE 2004)**

Subjective

57. N divisions on the main scale of a vernier calipers coincide with $(N+1)$ divisions on the vernier scale. If each division on the main scale is of a units, determine the least count of instruments. **(IIT-JEE 2003)**

Function, Differentiation as a Rate Measurement

Numerical Types/Integer Types

58. A person of height 1.6 m is walking away from a lamp post of height 4 m along a straight path on the flat ground. The lamp post and the person are always perpendicular to the ground. If the speed of the person is 60 cm s^{-1}, the speed of the tip of the person's shadow on the ground with respect to the person is _____ cm s^{-1}.

C-12.69 W-65.37 UA-21.94 (JEE Adv. 2023)

@FAREX PHYSICS

ANSWER KEY

JEE-Main

1. (b)	2. (c)	3. (c)	4. (b,d)	5. (a)	6. (c)	7. (b)	8. (c)	9. (b)	10. (d)
11. (b)	12. (d)	13. (a)	14. (c)	15. (b)	16. (c)	17. (b)	18. (a)	19. (b)	20. (d)
21. (c)	22. (b)	23. (a)	24. (c)	25. (a)	26. (a)	27. (c)	28. (a)	29. (b)	30. (d)
31. (a)	32. (a)	33. (d)	34. (d)	35. (c)	36. (c)	37. (c)	38. (b)	39. (d)	40. (c)
41. (c)	42. (b)	43. (a)	44. (a)	45. (b)	46. (d)	47. (c)	48. (b)	49. (a)	50. (b)
51. (a)	52. (a)	53. (a)	54. (d)	55. (d)	56. (c)	57. (c)	58. [4]	59. (c)	60. (b)
61. (c)	62. (c)	63. (a)	64. (b)	65. (c)	66. (*)	67. (a)	68. (d)	69. (c)	70. (a)
71. (a)	72. (c)	73. (c)	74. (a,b)	75. (c)	76. (b)	77. (c)	78. (b)	79. (a;b,d)	80. (c)
81. (b)	82. (4)	83. (c)	84. (2)	85. (c)	86. (b)	87. (c)	88. (b)	89. (a)	90. (c)
91. (c)	92. (a)	93. (d)	94. (c)	95. (a)	96. (c)	97. (c)	98. [1.99]	99. (b)	100. (a)
101. [18]	102. [150]	103. [5]	104. (b)	105. (c)	106. (b)	107. (a)	108. (a)	109. [1]	110. (b)
111. (b)	112. (b)	113. (b)	114. [14]	115. [5]	116. [34]	117. (a)	118. (b)	119. (c)	120. (*)
121. (c)	122. (c)	123. (c)	124. (b)	125. (b)	126. (b)	127. (d)	128. (c)	129. (a)	130. (b)
131. (a)	132. (d)	133. (d)	134. (b)	135. (b)	136. (a)	137. (b)	138. [220]	139. (c)	140. (c)
141. (c)	142. (a)	143. [180]	144. [412]	145. [5]	146. (b)	147. (b)	148. (b)	149. [25]	150. (a)
151. (b)	152. (c)	153. [52]	154. [13]	155. (c)	156. (b)	157. (*)	158. (c)	159. (b)	

JEE-Advanced

1. (a)	2. (c)	3. (a)	6. (b,d)	7. (a,c,d)	8. A-p,q B-r,s C-r,s D-r,s		11. (d)	12. (a)	13. (d)
14. (c)	15. (b)	16. (b,d)	17. (a, c, d)	18. (a,c)	19. (b,c)	20. (a, b, c)	21. (a, d)	22. (a, b, c)	
23. A-(r), B-(u), C-(p), D-(t), E-(q), F-(s)			27. (a)	28. (c)	29. (d)	30. (c)	31. (b)	32. (a, b)	33. (a,b,d)
34. [3]	35. [4]	36. (a)	37. (a)	38. (a)	39. (c)	40. (a,c)	41. (b)	42. (d)	43. (d)
44. (b)	45. (c)	47. (c)	48. (b)	49. (b)	50. (b)	51. (d)	52. (d)	53. (b,c)	54. [4]
55. [2.66]	56. [2.6]	58. [40]							

EXPLANATIONS

JEE-Main

1. (b) $\vec{E}=\frac{A}{x^2}\hat{i}+\frac{B}{y^3}\hat{j}$

$\left[\frac{A}{x^2}\right]=NC^{-1}\Rightarrow[A]=Nm^2C^{-1}$

$\left[\frac{B}{y^3}\right]=NC^{-1}\Rightarrow[B]=Nm^3C^{-1}$

2. (c) Unit of RH : m^{-1}, h : kgm^2s^{-1}, mB : $kgm^{-1}s^{-2}$, η : $kgm^{-1}s^{-1}$,

3. (c) $\frac{E}{H}=\frac{Volt/metre}{Ampere/metre}=\frac{Volt}{Ampere}=ohm$

4. (b,d) $\vec{S}=[\vec{E}\times\vec{B}]\frac{1}{\mu_0}$

$\vec{S}$ is pointing vector denotes flow of energy per unit area per unit time

5. (a) $128[M_1L_1^{-3}]=n_2[M_2L_2^{-3}]$

$\Rightarrow n_2=128\left[\frac{M_1}{M_2}\right]\left[\frac{L_1}{L_2}\right]^{-3}$

$=128\left[\frac{1000}{50}\right]\left[\frac{100}{25}\right]^{-3}$

$=\frac{128\times20}{64}=40$

6. (c) Heat = m L = L = heat/m

$\Rightarrow[L]=\frac{ML^2T^{-2}}{M}=M^0L^2T^{-2}$

7. (b) $E=\frac{Q}{4\pi\varepsilon_0R^2}\Rightarrow\varepsilon_0=\frac{Q}{4\pi R^2E}$

Now, $\varepsilon_0E^2=\frac{Q}{4\pi R^2E}\cdot E^2=\frac{Q}{4\pi R^2}\cdot E$

$\left[\varepsilon_0E^2\right]=\left[\frac{QE}{R^2}\right]=\frac{[Q][E]}{[R^2]}=\frac{[Q]}{[R^2]}\frac{[W]}{[Q][R]}$

$=\frac{[W]}{[R^3]}=\frac{ML^2T^{-2}}{L^3}=ML^{-1}T^{-2}$

8. (c) $s=\frac{\Delta Q}{m\Delta T}$

$[s]=\left[\frac{ML^2T^{-2}}{MK}\right]$

$[s]=\left[L^2T^{-2}K^{-1}\right]$

Statement-(I) is correct

$PV=nRT\Rightarrow R=\frac{PV}{nT}$

@FAKE_CBSE_X @RAJEDUNET

$$[R]=\frac{[ML^{-1}T^{-2}][L^3]}{[\text{mol}][K]}$$

$$[R]=[ML^2T^{-2}\,\text{mol}^{-1}K^{-1}]$$

Statement-II is incorrect

9. (b) $[\vec{\tau}]=[\vec{r}\times\vec{F}]=[ML^2T^{-2}]$

$$\Rightarrow B=\left(\frac{F}{qV}\right)=\left[\frac{MLT^{-2}}{ATLT^{-1}}\right]$$

$$=[MA^{-1}T^{-2}]$$

$[M]=[I\times A]=[AL^2]$

$$B=\frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

$$\Rightarrow[\mu]=\left[\frac{Br^2}{Idl}\right]=\left[\frac{MT^{-2}A^{-1}\times L^2}{AL}\right]$$

$$=[MLT^{-2}A^{-2}]$$

10. (d) D.O.f $(f)=5+2(3N-5)$

$$f=5+2(3\times2-1)=7$$

Energy of N molecule $=N\frac{f}{2}K_BT$

$$=10\left(\frac{f}{2}K_BT\right)=10\left(\frac{7}{2}K_BT\right)$$

$$=35\,K_BT$$

11. (b) Here, we have G is gravitational constant and u is the energy density.

$$[uG]=[(M^1L^{-1}T^{-2})(M^{-1}L^3T^{-2})]$$

$$=[M^0L^2T^{-4}]$$

So, $[\sqrt{uG}]=[L^1T^{-2}]$

12. (d) Change in angular momentum = Angular impulse

[Angular momentum] = [Angular impulse]

$\Rightarrow$ [mvr] = [M L² T⁻¹]

13. (a) [P] = MLT⁻¹

[τ] = ML²T⁻²

[h] = ML²T⁻¹

[L] = ML²T⁻¹

(Here P is linear momentum and τ is moment of force, h is Planck's constant, L is angular momentum).

14. (c) As we know,

$$F=\eta A\frac{dv}{dy},\quad L=mvr,\quad S.T=\frac{F}{\ell},$$

$$K.E=\frac{1}{2}I\omega^2$$

Hence,

$$F=\eta A\frac{dv}{dy},$$

$[MLT^{-2}]=\eta\,[L^2]\,[T^{-1}]$

$\eta=[ML^{-1}T^{-1}]$

$$S.T=\frac{F}{\ell}=\frac{[MLT^{-2}]}{[L]}=[ML^0T^{-2}]$$

$L=mvr=[ML^2T^{-1}]$

$$K.E=\frac{1}{2}I\omega^2=[ML^2T^{-2}]$$

15. (b) $Y=\frac{\text{Stress}}{\text{Strain}}=\frac{[ML^{-1}T^{-2}]}{[L^2]}=[ML^{-1}T^{-2}]$

$$\because\eta=\frac{F}{6\pi rv}\Rightarrow[\eta]=\frac{[MLT^{-2}]}{[L][LT^{-1}]}$$

$$=[ML^{-1}T^{-1}]$$

$$\because h=\frac{E}{\nu}\Rightarrow h=\frac{[ML^2T^{-2}]}{[T^{-1}]}=[ML^2T^{-1}]$$

Work function has same dimension as that of energy, so $[\phi]=[ML^2T^{-2}]$

16. (c) Pressure gradient

$$=\frac{\text{Pressure}}{\text{Length}}=\frac{[ML^{-1}T^{-2}]}{[L]}=[M^1L^{-2}T^{-2}]$$

$$\text{Energy density}=\frac{\text{energy}}{\text{volume}}=[M^1L^{-1}T^{-2}]$$

$$\text{Electric field}=\frac{\text{Force}}{\text{charge}}=\frac{[MLT^{-2}]}{[AT]}$$

$$=[M^1L^1T^{-3}A^{-1}]$$

$$\text{Latent heat}=\frac{\text{heat energy}}{\text{mass}}=\frac{[ML^2T^{-2}]}{[M]}$$

$$=[M^0L^2T^{-2}]$$

17. (b) (A) Surface Tension

$$=\frac{F}{\ell}=\frac{MLT^{-2}}{L}=MT^{-2}=\text{Kgs}^{-2}\Rightarrow\text{option (iv)}$$

(B) Pressure $=\frac{F}{A}=\frac{MLT^{-2}}{L^2}$

$=\text{Kgm}^{-1}\text{s}^{-2}\Rightarrow$ option (III)

(C)

$$\text{viscosity}=\frac{F}{A\left(\frac{dV}{dz}\right)}=\frac{MLT^{-2}}{L^2\left(\frac{LT^{-1}}{L}\right)}=ML^{-1}T^{-1}$$

$=\text{Kgm}^{-1}\text{s}^{-1}\Rightarrow$ option (I)

(D) impulse $=\int Fdt=MLT^{-2}\times T$

$=MLT^{-1}=\text{Kgms}^{-1}\Rightarrow$ option (II)

$\Rightarrow$ (A) - (IV), (B) - (III), (C) - (I), (D) - (II)

18. (a) Spring Constant

$$[K]=\frac{[F]}{[X]}=\frac{MLT^{-2}}{L}=MT^{-2}$$

$$\text{Angular speed }[\omega]=\frac{[\theta]}{[t]}=\frac{1}{T}=T^{-1}$$

Angular Momentum,

$[L]=[M]\,[V]\cdot[R]=[M]\,[LT^{-1}]\,[L]=[ML^2T^{-1}]$

Moment of Inertia,

$[I]=[M]\,[R^2]=[M]\,[L^2]=[ML^2]$

19. (b) [Stress]

$$=\frac{[F]}{[A]}=\frac{[MLT^{-2}]}{L^2}=[ML^{-1}T^{-2}]$$

[Pressure gradient]

$$=\frac{[P]}{[Z]}=\frac{[ML^{-1}T^{-2}]}{L^1}=[ML^{-2}T^{-2}]$$

[Torque] = [r][F] = [L][MLT⁻²]

= [ML²T⁻²]

[Angular Momentum] = [τ][t] = [ML²T⁻²][T]

= [ML²T⁻¹]

20. (d)

21. (c)

$$\because c^2=\frac{1}{\mu_0\epsilon_0}$$

$$\Rightarrow\left[\frac{1}{\mu_0\epsilon_0}\right]=[L^2T^{-2}]$$

22. (b) (A) Planck's constant

$$h=\frac{E}{\nu}=\frac{[M^1L^2T^{-2}]}{[T^{-1}]}=[M^1L^2T^{-1}]$$

(B) $E=qV$

$$V=\frac{E}{q}=\frac{[M^1L^2T^{-2}]}{[A^1T^1]}=[M^1L^2T^{-3}A^{-1}]$$

(C) ϕ (work function)

$=$ energy $=[M^1L^2T^{-2}]$

(D) Momentum (p) = F.t $=[M^1L^1T^{-2}T^1]$

$=[M^1L^1T^{-1}]$

23. (a) We know that,

Velocity gradient $=\frac{dv}{dx}$

Decay constant $(\lambda)=\frac{0.693}{T_{1/2}}$

∴ Dimension of velocity gradient

$$\left(\frac{dv}{dx}\right)=\frac{LT^{-1}}{L}=T^{-1}$$

24. (c)

$$e=-M\frac{di}{dt}\Rightarrow[M]=\frac{[e.m.f]}{\left[\frac{di}{dt}\right]}$$

$$=\frac{[ML^2T^{-2}A^{-1}T^{-1}]}{[AT^{-1}]}=[ML^2T^{-2}A^{-2}]$$

@TAKE_CBSE_X @RAJ_FB.NET

25. (a)

$$[\text{Pascal-second}] = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-1}]$$

26. (a) Unit of Viscosity = Pascal.Second,
Therefore, dimension of viscosity
$= [ML^{-1}T^{-1}]$
According to question,
$[ML^{-1}T^{-1}] = P^x A^y T^z$
$[M^1L^{-1}T^{-1}][L^2]^y[T]^z = [M^1L^{-1}T^{-1}]$
$[M^xL^{x+2y}T^{-x+z}] = M^1L^{-1}T^{-1}$
$x = 1, x + 2y = -1, -x + z = 1$
$y = -1, z = 0$
Viscosity $= [P^1A^{-1}T^0]$

27. (c) $\frac{B^2}{\mu_0}$ is energy density in magnetic field.

$$\therefore \left[\frac{B^2}{\mu_0}\right] = [\text{Energy density}]$$

= [Energy]/[Volume]

$$= \frac{[ML^2T^{-2}]}{[L^3]} = [ML^{-1}T^{-2}]$$

28. (a) Electric Displacement, $\bar{D} = \epsilon_0 \bar{E}$
$[D] = [\epsilon_0][E] = [M^{-1}L^{-3}T^4A^2][ML^1A^{-1}T^{-3}]$
$= [L^{-2}TA]$
Surface charge density,(σ)

$$\sigma = \frac{Q}{A} \Rightarrow [\sigma] = \frac{[Q]}{[A]} = \frac{[AT]}{[L^2]} = [L^{-2}AT]$$

Electric displacement ($\bar{D}$) and surface charge density (δ) have the same dimension.

29. (b) Torque $= \bar{r} \times \bar{F}$ (Nm)

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} \ (\text{N/m}^2)$$

$$\text{Latent heat} = \frac{\text{Energy}}{\text{Mass}} \ (\text{J kg}^{-1})$$

$$\text{Power} = \frac{\text{Work}}{\text{Time}} \ (\text{N ms}^{-1})$$

30. (d) $\Delta Q = ms\Delta T \Rightarrow [s] = \frac{[\Delta Q]}{[m][\Delta T]}$

$$\Rightarrow [s] = \frac{[ML^2T^{-2}]}{[MK]} = L^2T^{-2}K^{-1}$$

$$\Delta Q = mL \Rightarrow [L] = \frac{ML^2T^{-2}}{M} = L^2T^{-2}$$

31. (a) Capacitance

$$[C] = \frac{Q}{V} = \frac{Q}{W/Q} = \frac{Q^2}{W} = \frac{A^2T^2}{M^1L^2T^{-2}}$$

$$= M^{-1}L^{-2}T^4A^2$$

Permittivity $[\varepsilon_0] = M^{-1}L^{-3}T^4A^2$

$$C = \frac{1}{\sqrt{\mu_0\varepsilon_0}} \Rightarrow \mu_0 = \frac{1}{\varepsilon_0 c^2}$$

$\Rightarrow$ Permeability of freespace $[\mu_0]$
$= [M^1L^1T^{-2}A^{-2}]$
Electric field, $E = \frac{F}{q} = \frac{MLT^{-2}}{AT}$

$\Rightarrow [E] = MLT^{-3}A^{-1}$

32. (a) $P = EL^2M^{-3}G^{-2}$
$= [MLT^{-2}][ML^2T^{-1}]^2[M^{-3}][M^{-1}L^3T^{-2}]^2$
$= M^0L^0T^0$

33. (d) $\lambda = \frac{C}{V} = \frac{Q/V}{V} = \frac{Q}{V^2} = \frac{Q^2}{W^2} = \frac{I^2T^2}{F^2 \cdot d^2}$

$$\Rightarrow [\lambda] = \frac{[I^2T^2]}{[M^2L^4T^{-4}]} = [M^{-2}L^{-4}T^2I^2]$$

34. (d)
The dimension of $[\mu_0] = [M^1L^1T^{-2}A^{-2}]$

$$\left[\because \mu_0 = \frac{B_0}{H} = NA^{-2}\right]$$

It is not dimensionless

35. (c) $[h] = [ML^2T^{-1}]$
$[E] = [ML^2T^{-2}]$
$[V] = [ML^2T^{-3}I^{-1}]$
$[P] = [MLT^{-1}]$

36. (c) We know that, $[F] = MLT^{-2}$
$\Rightarrow M = FL^{-1}T^2$
$[\rho] = ML^{-3} = FL^{-1}T^2L^{-3} = FL^{-4}T^2$

37. (c)
(a) Torque $\rightarrow ML^2T^{-2} \rightarrow$ (iii)
(b) Impulse $\rightarrow MLT^{-1} \rightarrow$ (i)
(c) Tension $\rightarrow MLT^{-2} \rightarrow$ (iv)
(d) surface Tension

$$\rightarrow \frac{MLT^{-2}}{L} = MT^{-2} \rightarrow \text{(ii)}$$

38. (b) $p = kS^aI^bh^c$
where k is dimensionless constant
$MLT^{-1} = (MT^{-2})^a(ML^2)^b(ML^2T^{-1})^c$
$a + b + c = 1$ ...(i)
$2b + 2c = 1$ ...(ii)
$-2a - c = -1$ ...(iii)
On solving the above equations
$a = \frac{1}{2} \quad b = \frac{1}{2} \quad c = 0$
Thus, $p \propto S^{1/2}I^{1/2}h^0$

39. (d) Dimension for permittivity $[\varepsilon_0] = M^{-1}L^{-3}T^4A^2$
Dimension for permeability $[\mu_0] = MLT^{-2}A^{-2}$
Dimension for electrical resistance $[R] = ML^2T^{-3}A^{-2}$
Using the given options

$$[R] = \sqrt{\frac{\mu_0}{\varepsilon_0}}$$

40. (c) Dimension of

$$\sqrt{\frac{\varepsilon_0}{\mu_0}} = \left[\frac{M^{-1}L^{-3}T^4A^2}{MLT^{-2}A^{-2}}\right] = [M^{-1}L^{-2}T^3A^2]$$

41. (c) Since, $T^2 = \frac{4\pi^2r^3}{GM}$

$$[T^2] = \frac{[L^3]}{[M^{-1}L^3T^{-2}][M]}$$

(Dimension of G is $[M^{-1}L^3T^{-2}]$)

$$[T^2] = \frac{[L^3]}{[L^3T^{-2}]} = [T^2]$$

42. (b) Dimension formula for [B] = L^2

$$A = \frac{x^2}{tE} = \frac{L^2}{TML^2T^{-2}} = \frac{1}{MT^{-1}}$$

Dimension formula for [A]= $M^{-1}T$
Dimension formula for [AB]
$= L^2M^{-1}T^1$

43. (a) Force, $F = ax^2 + bt^{1/2}$

$$[a] = \frac{[F]}{[x^2]} = [M^1L^1T^{-2}]$$

$$[b] = \frac{[F]}{[t^{1/2}]} = [M^1L^1T^{-5/2}]$$

$$\left[\frac{b^2}{a}\right] = \frac{[M^2L^2T^{-5}]}{[M^1L^1T^{-2}]} = [M^1L^3T^{-3}]$$

44. (a) $m = k\,c^p\,G^{-1/2}\,h^{1/2}$
$M^1L^0T^0 = [LT^{-1}]^p[M^{-1}L^3T^{-2}]^{-1/2}[ML^2T^{-1}]^{1/2}$
By comparing P = 1/2

45. (b) $[P] = \left[\frac{a}{V^2}\right] \Rightarrow [a] = [PV^2]$

And dimension of V = dimension of b

$$\therefore \frac{[a]}{[b^2]} = \frac{[PV^2]}{[V^2]} = [P]$$

46. (d) According to the question, $m \propto h^x c^y G$

$$M^1 = (ML^2T^{-1})^x (LT^{-1})(M^{-1}L^3T^{-2})^z$$

$$M^1L^0T^0 = M^{x-z}L^{2x+y+3z}T^{-x-y-2z}$$

on comparing both sides
$x - z = 1$ ...(i)
$2x + y + 3z = 0$ ...(ii)
$-x - y - 2z = 0$ ...(iii)
On solving equations (i), (ii) and (iii) we get

$$x = \frac{1}{2}, y = \frac{1}{2}, z = \frac{-1}{2}$$

@FAKE_CBSE_GRAJ_FEDNET

47. (c) b has the dimensions of volume, $[b] = [V]$

$\ell \left[\frac{a}{V^2}\right] = [P]$

$\Rightarrow \left[\frac{a}{b^2}\right] = [P] \therefore \left[\frac{b^2}{a}\right] = \frac{1}{[P]} = \frac{1}{[B]} = [K]$

$\therefore \left[\frac{b^2}{a}\right] = \frac{1}{[P]} = \frac{1}{[B]} = [K]$

48. (b) $(x - At)^2 + \left(y - \frac{t}{B}\right)^2 = a^2$

$[At] = [L]$

$\therefore [A] = \left[T^1 L^1\right]$ {ℓ dimension of $t = [T^{-1}]$}

Similarly,

$\left[\frac{t}{B}\right] = [L] \Rightarrow \frac{1}{T[B]} = [L]$

$\therefore [B] = \left[T^{-1} L^{-1}\right]$

49. (a) $\left[T^{-1}\right] = \left[L^1\right]^a \left[M^1 L^{-3}\right]^b \left[\frac{MLT^{-2}}{L}\right]^c$

$\Rightarrow \left[T^{-1}\right] = \left[M^{b+c} \cdot L^{a-3b} \cdot T^{-2c}\right]$

Equating the power,

$c = \frac{1}{2}, b = -\frac{1}{2}, a - 3b = 0 \Rightarrow a = -\frac{3}{2}$

50. (b) $[ML^{-3}] = [MLT^{-2}]^a [LT^{-1}]^b [T]^c$

$= [M^a L^{a+b} T^{2a-b+c}]$

$a = 1,$ ...(i)

$a + b = -3,$ ...(ii)

$2a - b + c = 0$ ... (iii)

Solving (i), (ii) and (iii)

$c = -2 \Rightarrow b = -4$

51. (a) X and $\frac{a}{Y^2}$ have same dimensions

Y and b have same dimensions

$\therefore [a] = [ML^5 T^{-2}]$ $[b] = [L^3]$

$\frac{[a]}{[b]} = [ML^2 T^{-2}]$ has dimensions of energy

52. (a) $Y = c^\alpha h^\beta G^\gamma$

$[ML^{-1}T^{-2}] = [LT^{-1}]^\alpha [ML^2T^{-1}]^\beta [M^{-1}L^3T^{-2}]^\gamma$

$[ML^{-1}T^2] = [M^{\beta-\gamma}] [L^{\alpha+2\beta+3\gamma}] [T^{-\alpha-\beta-2\gamma}]$

$1 = \beta - \gamma$ ...(i)

$-1 = \alpha + 2\beta + 3\gamma$ ...(ii)

$-2 = -\alpha - \beta - 2\gamma$ ...(iii)

After solving above equations

$\alpha = 7, \beta = -1, \gamma = -2$

53. (a) Given that,

$v_2 = \frac{n}{m^2} v_2 \Rightarrow \frac{L_2}{T_2} = \frac{n}{m^2} \frac{L_1}{T_1}$ ...(i)

Also, $a_2 = a_1/mn \Rightarrow \frac{L_2}{T_2^2} = \frac{L_1}{T_1^2} \times \frac{1}{mn}$

$\Rightarrow \left(\frac{T_1}{T_2}\right)^2 = \frac{L_1}{L_2} \times \frac{1}{mn}$

On Putting the volue of $\frac{L_1}{L_2}$ from (i)

$\left(\frac{T_1}{T_2}\right)^2 = \frac{T_1}{T_2} \times \frac{m^2}{n} \times \frac{1}{mn}$

$\Rightarrow \frac{n^2}{m} T_1 = T_2$ ...(ii)

Solving (i) and (ii), we get

$L_2 = \frac{n^3}{m^3} L_1$

54. (d) Given, $u = \frac{\alpha}{\beta} \sin\left(\frac{\alpha x}{kt}\right)$

Dimension of Boltzmann Constant,

$[k] \rightarrow [M^1 L^2 T^{-2} K^{-1}]$

Dimension of Energy density

$[\mu] \rightarrow \left[ML^{-1}T^{-2}\right]$

Dimension of Temperature $[t] = [K]$

Since, angle has no dimension, therefore its dimensional formula is $[M^0L^0T^0]$

or $\frac{\alpha x}{kt} = \left[M^0 L^0 T^0\right]$

$\Rightarrow \frac{\alpha [L]}{\left[ML^2 T^{-2} K^{-1} K\right]} = \left[M^0 L^0 T^0\right]$

$\alpha = \left[MLT^{-2}\right]$

Also, dimension of $\frac{\alpha}{\beta}$ = dimension of energy density

$\frac{\alpha}{\beta} = \left[ML^{-1}T^{-2}\right]$

$\beta = \frac{\left[MLT^{-2}\right]}{\left[ML^{-1}T^{-2}\right]} = \left[M^0 L^2 T^0\right]$

55. (d) Trigonometric function and logarithmic function are dimensionless quantities.

$\therefore [\eta] = [M^0L^0T^0]$

Also, dimensions of temperature,

$[T] = [M^0L^0T^0K]$

Dimensions of Boltzmann constant, [k] $= [ML^2T^{-2}K^{-1}]$

Dimension of $[x] = [M^0LT^0]$

A. $[\beta] = \left[\frac{kT}{x}\right] = \left[\frac{E}{x}\right] = [MLT^{-2}] = [F]$

B. $[\alpha\beta] = [M^0L^0T^0] \Rightarrow [\alpha]^{-1} = [\beta] = \left[\frac{kT}{x}\right]$

So $[\alpha]^{-1}[x] = [kT] = [ML^2T^{-2}]$

C. $\eta \sin\theta = \alpha\beta$

So, $[\eta \sin\theta] = [\alpha\beta]$

$[\eta] = [M^0L^0T^0]$ it is dimensionless quantity

D. $[\alpha] \neq [\beta]$

56. (c)

$\frac{kt}{\beta x} = 1 \Rightarrow [\beta] = \left[\frac{kt}{x}\right] = \left[\frac{ML^2T^{-2}}{L}\right]$

$\left(\because E = \frac{1}{2}kt\right)$

As P is dimensionless

$\Rightarrow [\alpha] = [\beta] = [MLT^{-2}]$

57. (c) From principle of homogeinity,

$[P] = \left[\frac{a}{V^2}\right]$ and $[b] = [V] \Rightarrow \left[\frac{a}{b}\right] = [PV]$

58. [4] $MT^{-2}I^{-1} = [LT]^\alpha [M]^\beta [ML^2T^{-1}]^\gamma [ML^3T^{-4}I^{-2}]^\delta$

$\therefore \beta + \gamma + \delta = 1$ ...(i)

$2\gamma + 3\delta = 0$ ...(ii)

$\alpha - \gamma - 4\delta = -2$ ...(iii)

$\alpha - 2\delta = -1$ ...(iv)

On solving these equations, we get

$\alpha + \beta + \gamma + \delta = 4$

59. (c) Let us suppose,

Mass $\alpha [t^a v^b \ell^c] \Rightarrow [M^1 L^0 T^0] \equiv T^a \times [LT^{-1}]^b \times [ML^2T^{-1}]^c$

On equating both sides, we get

$\Rightarrow a - b - c = 0;$ *c = 1, and* $b + 2c = 0$

$\Rightarrow b = -2c = -2$

$\Rightarrow a = b + c = 1 - 2 = -1$

Hence, dimension of mass $= [t^a v^b \ell^c] = [t^{-1} v^{-2} \ell^1]$

60. (b) We have, $W = \alpha^2 \beta e^{\frac{\beta x^2}{kT}}$

$\therefore \left[\beta x^2\right] = [kT] = \left[ML^2T^{-2}\right] \left[\therefore E = \frac{3}{2}kT\right]$

$\Rightarrow [\beta] = [MT^{-2}]$

And, $[W] = [\alpha^2\beta] \Rightarrow [ML^2T^2] = [\alpha^2][MT^{-2}]$

$\Rightarrow [\alpha] = [L]$

61. (c) Workdone, $[W] = [\tau\theta] = \left[ML^2T^{-2}\right] \rightarrow$ correct

height, $[h] = [L] = \left[\frac{2s\cos\theta}{\rho r g}\right] \rightarrow$ correct

Volume, $[V] = \left[L^3\right]; \left[\frac{\pi p a^4}{8\eta L}\right] = \left[L^3T^{-1}\right] \rightarrow$ incorrect

Current density, $J = \varepsilon \frac{\partial E}{\partial t} \rightarrow$ correct

62. (c)

$\frac{1}{4\pi\varepsilon_0} \frac{|e|^2}{hc} = \frac{1}{4\pi\varepsilon_0} \frac{|e|^2}{r^2} \times \frac{r^2}{\frac{hc}{\lambda} \times \lambda} = \frac{Fr \times r}{E \times \lambda}$

Dimension of 'Fr' and 'E' are same.

Therefore, given quantity is dimensionless

63. (a) Since, $\frac{x^2}{\alpha kT}$ should be dimensionless.

$\therefore [\alpha] = \frac{L^2}{ML^2T^{-2}} = M^{-1}T^2$

[KT] = [Energy

@FREE_CBSE_X@RAJ_BOARD.NET

Dimension of $\alpha\beta^2$ should be dimension of W.

So, $[\alpha\beta^2] = ML^2T^{-2}$

$\Rightarrow [\beta^2] = \frac{ML^2T^{-2}}{M^{-1}T^4} = M^2L^2T^{-4}$

$\Rightarrow [\beta] = MLT^{-3}$

64. (b) Let $M = K(V)^x(F)^y(T)^z$

$\Rightarrow$ Equating dimensions of both the sides

$M^1L^0T^0 = (1)[L^1T^{-1}]^x[M^1L^1T^{-2}]^y[T^1]^z$

$M^1L^0T^0 = M^yL^{x+y}T^{-x-2y+z}$

Comparing dimensions, we get

$a = -1, b = 1, c = 1$

Thus, M = (Some Number) $(V^{-1}F^1T^1)$

$\Rightarrow [M] = [V^{-1}F^1T^1]$

65. (c) $[A] = [MLT^{-2}]$

$[B] = [L^{-1}]$,

$[D] = [T^{-1}]$

$\Rightarrow \left[\frac{AD}{B}\right] = \frac{[MLT^{-2}][T^{-1}]}{[L^{-1}]}$ or

$\left[\frac{AD}{B}\right] = [ML^2T^{-3}]$

66. (*) $I^x = K(h)^x (l)^y (G)^y (C)^w$ (V is voltage)

We know, $[h] = ML^2T^{-1}$

$[I] = A$, $[G] = M^{-1}L^3T^{-2}$

$[C] = LT^{-1}$, $[I^x] = ML^2T^{-3}A^{-1}$

$ML^2T^{-3}A^{-1} = (ML^2T^{-1})^x (A)^y (M^{-1}L^3T^{-2})^z (LT^{-1})^w$

$ML^2T^{-3}A^{-1} = M^{x-z}L^{2x+3z+w}T^{-x-2z-w}A^y$

$x - z = 1$ ...(i)

$2x + 3z + w = 2$ ...(ii)

$-x - 2z - w = -3$ ...(iii)

$y = -1$ ...(iv)

On solving,

$z = -1, x = 0, w = 5, y = -1$

Hence, $V = K(h)^0 (l)^{-1}(G)^{-1}(C)^5$ (Bonus)

67. (a) $K_{th} = \frac{QDx}{ADTt}$

Dimensional formula $= \frac{(ML^2T^{-2})(L)}{(L^2)(K)(T)}$

$= M^1L^1T^{-3}K^{-1}$

68. (d) Solar constant $= \frac{E}{AT}$

$\frac{M^1L^2T^{-2}}{L^2T} = M^1T^{-3}$

69. (c) $x = \frac{IFv^2}{WL^4}$

$\therefore [x] = \frac{(ML^2)\times(MLT^{-2})\times(LT^{-1})^2}{(ML^2T^{-2})\times L^4}$

$= ML^{-1}T^{-2} = [\text{Energy density}]$

70. (a) Planck's constant, $(h) = [M^1L^2T^{-1}]$

Speed of light, $(c) = [L^1T^{-1}]$

Universal gravitational constant

$(G) = [M^{-1}L^3T^{-2}]$

$[f] = \frac{\sqrt{M^1L^2T^{-1}\times L^3\times T^{-5}}}{\sqrt{M^{-1}L^3T^{-2}}} = M^1L^2T^{-2}$

71. (a) ℓ [Young's modulus] $= \left[\frac{\text{Force}}{\text{Area}}\right]$

$\Rightarrow$ [Young's modulus] $= FA^{-1}$

$\Rightarrow$ [Young's modulus] $= FA^{-1}V^0$

72. (c) Energy = Force × Distance

$\Rightarrow$ [Energy] $= \frac{P}{T}\times\sqrt{A} = \left[PA^{\frac{1}{2}}T^{-1}\right]$

73. (c) $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = x \Rightarrow c = \frac{E}{B} = y$

$\tau = RC = t \Rightarrow \frac{\ell}{RC} = LT^{-1}$

$\Rightarrow [x] = [y] = [z]$

74. (a,b) Position $= [x^a] \Rightarrow [L] = [x^a]$ ...(i)

Speed $= x^b \Rightarrow LT^{-1} = x^b$

$x^aT^{-1} = x^b$ [From (i)]

$T^{-1} = x^{b-a}$ ...(ii)

Acceleration $= x^p \Rightarrow LT^{-1}\times T^{-1} = x^p$

$x^bx^{b-a} = x^p \Rightarrow 2\beta - \alpha = p \Rightarrow \alpha + p = 2\beta$

Option (a)

[Linear momentum] $= x^q$

$MLT^{-1} = x^q \Rightarrow M.x^b = x^q$

$M = x^{q-\beta}$ ...(iii)

[force] $= x^r \Rightarrow MLT^{-2} = x^r$

$M.X^p = x^r$

$M = x^{r-p}$ ... (iv)

From (iii) and (iv)

$q - \beta = r - p \Rightarrow p + q - r = \beta$

75. (c) $t = G^ah^bc^c$

$\Rightarrow M^0L^0T^1 = (M^{-1}L^3T^{-2})^a (ML^2T^{-1})^b (LT^{-1})^c$

$\Rightarrow -a + b = 0 \Rightarrow a = b$,

$3a + 2b + c = 0 \Rightarrow c = -5a$,

$-2a - b - c = 1$

$\Rightarrow a = \frac{1}{2}; b = \frac{1}{2}; c = \frac{-5}{2}$

76. (b) Power of exponential should be dimensionless.

$\therefore [x^2] = [\alpha tk] \Rightarrow [L^2] = [\alpha]\,[ML^2T^{-2}]$

$\Rightarrow [\alpha] = [M^{-1}T^2]$

$\therefore [F] = [\alpha]\,[\beta] \Rightarrow [MLT^{-2}] = [M^{-1}T^2]\,[\beta]$

$\therefore [\beta] = [M^2LT^{-4}]$

77. (c) $\ell\,[Y] = [F]^a\,[V]^b\,[A]^c$

$[ML^{-1}T^{-2}] = [MLT^{-2}]^a\,[LT^{-1}]^b\,[LT^{-2}]^c$

$[ML^{-1}T^{-2}] = [M^aL^{1+b+c}T^{-2a-b-2c}]$

$\therefore a = 1$ ...(i)

$1 + b + c = -1$ ...(ii)

$-2a - b - 2c = -2$ ...(iii)

After solving above equations (i), (ii) and (iii).

$a = 1, b = -4, c = 2 \Rightarrow \therefore [Y] = [V^{-4}A^2F]$

78. (b) Time constant $\tau = RC \Rightarrow [RC] = T$

$\Rightarrow V = L\frac{dI}{dt} \Rightarrow \left[\frac{L}{V}\right] = TA^{-1}$

Thus, $\left[\frac{L}{RCV}\right] = \frac{TA^{-1}}{T} = A^{-1}$

79. (a,b,d) Mass $= M^1L^0T^0$

$Mvr = M^1L^0T^0 \Rightarrow M^1\frac{L^1}{T^1}.L^1 = M^1L^0T^0$ ...(i)

$L^2 = T^1$ (in SI)

Force $= M^1L^1T^{-2}$

$= M^1L^1L^{-4}$ [In new system from equation (i)]

$= L^{-3}$

Energy $= M^1L^2T^{-2}$ (In SI)

$= M^1L^2L^{-4}$ [In new system from equation (i)]

$= L^{-2}$

Power $= \frac{\text{Energy}}{\text{Time}} = M^1L^2T^{-3}$ (in SI)

$= M^1L^2L^{-6}$

[In new system from equation (i)]

$= L^{-4}$

Linear momentum $= M^1L^1T^{-1}$

(in SI) $= M^1L^1L^{-2}$

[In new system from equation(i)]

$= L^{-1}$

80. (c) For finding percentage error in Y,

$\frac{\Delta Y}{Y} = \frac{\Delta m}{m} + \frac{\Delta \ell}{\ell}$

$= \frac{5}{500} + \frac{0.02}{2} = 0.01 + 0.01$

$\frac{\Delta Y}{Y} = 0.02 \Rightarrow \%\frac{\Delta Y}{Y} = 2\%$

81. (b) if $a \le 5$ order is b

$a > 5$ order is $b + 1$

82. (4) From $T = 2\pi\sqrt{\frac{m}{k}}$

Since, $T^2 \propto \sqrt{\frac{m}{k}}$

Therefore,

$\frac{2\Delta T}{T}\% = \frac{\Delta m}{m}\% - \frac{\Delta k}{k}\%$

$\frac{k}{T}\% = \frac{\Delta m}{m}\% - \frac{2\Delta T}{T}\%$

$\frac{\Delta k}{k}\% = (-1)\% - 2(2)\% = |5\%|$

$= 5\%$

83. (c) Sum of number by considering significant digit sum = 4.6 + 4.6 + 4.6 + 4.6 = 18.4

@FAST CBSE X @RAJ EDUNET

Arithmetic Mean

$$= \frac{\text{sum}}{4} = \frac{18.4}{4} = 4.6$$

84. (2) According to lens Formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow f^{-1} = v^{-1} - u^{-1}$$

differentiating w.r.t f

$$\Rightarrow -f^{-2}df = -v^{-2}dv - u^{-2}du$$

$$\Rightarrow \frac{df}{f^2} = \frac{dv}{v^2} + \frac{du}{u^2}$$

$$\Rightarrow df = f^2\left[\frac{dv}{v^2} + \frac{du}{u^2}\right]$$

85. (c) Conceptual

86. (b) Resistivity of the given material,

$$\rho = R\frac{\rho}{\ell}$$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta R}{R} + 2\frac{\Delta r}{r} + \frac{\Delta\ell}{\ell}$$

$$= \frac{10}{100} + 2\times\frac{0.05}{0.35} + \frac{0.2}{15}$$

$$= \frac{1}{10} + \frac{2}{7} + \frac{1}{75} = 39.9\%$$

87. (c) Time period of pendulum,

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

$$g = \frac{4\pi^2\ell}{T^2}$$

Percentage error, $\frac{\Delta g}{g} = \frac{\Delta\ell}{\ell} + \frac{2\Delta T}{T}$

$$= \frac{0.2}{20} + 2\left(\frac{1}{40}\right) = \frac{0.3}{20}$$

Percentage change $= \frac{0.3}{20}\times 100 = 6\%$

88. (b) Resistance, $R = \frac{\rho L}{\pi\frac{d^2}{4}}$

$$\frac{\Delta R}{R} = \frac{\Delta L}{L} + \frac{2\Delta d}{d}$$

$\frac{\Delta L}{L} = 0.1\%$ and $\frac{\Delta d}{d} = 0.1\%$

Percentage error in resistance is

$$\frac{\Delta R}{R} = 0.3\%$$

89. (a) Given $V = (200 \pm 5)$ V

$I = (20 \pm 0.2$ A)

$$R = \frac{V}{T}$$

According to error analysis

$$\frac{dR}{R} = \frac{dV}{V} + \frac{dI}{I}$$

$$\frac{dR}{R} = \frac{5}{200} + \frac{0.2}{20} = \frac{5}{200} + \frac{2}{200}$$

$$\frac{dR}{R} = \frac{7}{200}$$

% error $\frac{dR}{R}\times 100 = \frac{7}{200}\times 100 = 3.5\%$

90. (c) $Q = \frac{a^4b^3}{c^2}$

By using the percentage error formula,

$$\frac{\Delta Q}{Q} = 4\frac{\Delta a}{a} + \frac{\Delta b}{b} + 2\frac{\Delta c}{c}$$

$$\frac{\Delta Q}{Q} = 100 = 4\left(\frac{\Delta a}{a}\times 100\right) +$$

$$3\left(\frac{\Delta b}{b}\times 100\right) + 2\left(\frac{\Delta c}{c}\times 100\right)$$

% error in $Q = 4\times 3\% + 3\times 4\% + 2\times 5\%$

$= 12\% + 12\% + 10\% = 34\%$

91. (c) Least count is 0.2 cm

$$u = (100\pm 0.2) - (80\pm 0.2) = (20\pm 0.4)\text{cm}$$

$$v = (180\pm 0.2) - (100\pm 0.2) = (80\pm 0.4)\,cm$$

From lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{80} - \frac{1}{-20} = \frac{-20-80}{-1600}$$

$f = 16$ cm

Also $\frac{\Delta f}{f^2} = \frac{\Delta v}{v^2} + \frac{\Delta u}{u^2}$

$$\therefore \frac{\Delta f}{f}\times 100 = \left(\frac{\Delta v}{v^2} + \frac{\Delta u}{u^2}\right)\times f\times 100$$

$$\Rightarrow \%f = \left(\frac{0.4}{400} + \frac{0.4}{6400}\right)\times 16\times 100 = 1.70$$

92. (a) Percentage error in quantity P,

$$\frac{\Delta P}{P}\times 100\%$$

$$= \left(2\frac{\Delta a}{a} + 3\frac{\Delta b}{b} + \frac{\Delta c}{c} + \frac{1}{2}\frac{\Delta d}{d}\right)\times 100\%$$

$$= 2(1\%) + 3(2\%) + 3\% + \frac{1}{2}\times 4\%$$

$= 2\% + 6\% + 3\% + 2\% = 13\%$

93. (d) Terminal velocity of a spherical body in liquid

$$V_t = \frac{2}{9}r^2\frac{(\rho-\delta)g}{\eta} \Rightarrow V_t \propto r^2$$

$$\Rightarrow \frac{\Delta V_t}{V_t} = 2\cdot\frac{\Delta r}{r}$$

$$\Rightarrow \frac{\Delta V_t}{V_t}\times 100\% = 2\frac{(0.1)}{5}\times 100 = 4\%$$

94. (c) When R_1 and R_2 are connected in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \quad \ldots(i)$$

$$\left[R = \frac{R_1R_2}{R_1+R_2} = \frac{10\times 15}{10+15} = 6\right]$$

Differentiating (i) both sides

$$\frac{\Delta R}{R^2} = \frac{\Delta R_1}{R_1^2} + \frac{\Delta R_2}{R_2^2}$$

$$\Rightarrow \frac{\Delta R}{R} = \left(\frac{\Delta R_1}{R_1^2} + \frac{\Delta R_2}{R_2^2}\right)R$$

$$= \left(\frac{0.5}{100} + \frac{0.5}{225}\right)6 = \frac{13}{300}$$

$$\frac{\Delta R}{R}\times 100 = \frac{13}{3} = 4.33\%$$

95. (a) K.E. $= K \pm \Delta K$

$$= K \pm K\left(\frac{\Delta m}{m} + \frac{2\Delta v}{v}\right)\left(\because \frac{\Delta K}{K} = \frac{\Delta m}{m} + \frac{2\Delta v}{v}\right)$$

$$= 1000 \pm 1000\left(\frac{0.5}{5} + \frac{2\times 0.4}{20}\right)$$

$= (1000 \pm 140)\,J$

96. (c)

$$\rho = \frac{m}{\pi r^2 l} \Rightarrow \left|\frac{d\rho}{\rho}\right|_{max} = \left|\frac{dm}{m}\right| + 2\left|\frac{dr}{r}\right| + \left|\frac{dl}{l}\right|$$

$$= \frac{0.01}{0.4} + \frac{2(0.03)}{6} + \frac{0.04}{8} = 0.04$$

Percentage error in density

$$= \left(\frac{d\rho}{\rho}\right)\times 100\% = 4\%$$

97. (c) $z = \frac{A^2B^3}{C^4}$

The relative error in z can be given as

$$\frac{\Delta z}{z} = \frac{2\Delta A}{A} + \frac{3\Delta B}{B} + \frac{4\Delta C}{C}$$

98. [1.99] $L = 1$m, $\Delta L = 0.4\times 10^{-3}$m

$m = 1$kg, $d = 0.4\times 10^{-3}$m

Area, $A = \frac{\pi d^2}{4} = \frac{3.14\times(0.4\times 10^{-3})^2}{4}$

$= 0.1256\times 10^{-6}\,m^2$

Young's modulus

$$y = \frac{FL}{A\Delta L} = \frac{(1\times 10)\times 1}{0.1256\times 10^{-6}\times 0.4\times 10^{-3}}$$

$[\because F = mg]$

$y = 0.1999\times 10^{12}$ N/m^2

Now, $\frac{\Delta Y}{Y} = \frac{\Delta F}{F} + \frac{\Delta L}{L} + \frac{\Delta A}{A} + \Delta\left(\frac{\Delta L}{\Delta L}\right)$

$$= \frac{2\Delta d}{d} + \frac{\Delta(\Delta L)}{\Delta L} = 2\times\frac{0.01}{0.4} + \frac{0.02}{0.4}$$

$\Delta y = 0.1\times 0.199\times 10^{12} = 1.99\times 10^{10}$

$= 1.99$

@FAKE_CBSE_X@RAJ_EDUNET

99. (*b*) For torque
$[\tau] = [ML^2T^{-2}]$
So, percentage error in torque = $\%\tau$
$= \%M + 2(\%L) + 2(\%T) = 25\%$

100. (*a*) Given, $m = 0.6 \pm 0.006$, $r = 0.5 \pm 0.005$, $l = 4 \pm 0.04$
Percentage error in m,
$$\frac{\Delta m}{m}\times 100 = \frac{0.006}{0.6}\times 100 = 1\%$$
Percentage error in r,
$$\frac{\Delta r}{r}\times 100 = \frac{0.005}{0.5}\times 100 = 1\%$$
Percentage error in l,
$$\frac{\Delta l}{l}\times 100 = \frac{0.04}{4}\times 100 = 1\%$$
Formula of density $\Rightarrow \rho = \frac{m}{V} = \frac{m}{\pi r^2 l}$
$$\therefore \frac{\Delta\rho}{\rho}\times 100 = \frac{\Delta m}{m}\times 100 + 2\frac{\Delta r}{r}\times 100 + \frac{\Delta l}{l}\times 100$$
$= 1 + 2 \times 1 + 1 = 4\%$.

101. [18] We have, $z = a^2x^2y^{1/2}$
$$\frac{\Delta z}{z}\times 100 = 3\frac{\Delta x}{x}\times 100 + \frac{1}{2}\frac{\Delta y}{y}\times 100$$
$$= \left(3\times 4 + \frac{1}{2}\times 12\right)\times 100 = 18\%$$

102. [150] It is given that, $x_1 = 1.22$ mm, $x_2 = 1.23$ mm,
$x_3 = 1.19$ mm and $x_4 = 1.20$ mm
$$x_{mean} = \frac{x_1 + x_2 + x_3 + x_4}{4}$$
$$= \frac{1.22 + 1.23 + 1.19 + 1.20}{4} = 1.21$$
$|\Delta x_1| = |x_{mean} - x_1| = |1.21 - 1.22| = 0.01$
$|\Delta x_2| = |x_{mean} - x_2| = |1.21 - 1.23| = 0.02$
$|\Delta x_3| = |x_{mean} - x_3| = |1.21 - 1.19| = 0.02$
$|\Delta x_4| = |x_{mean} - x_4| = |1.21 - 1.20| = 0.01$
$$(\Delta x)_{mean} = \frac{0.01 + 0.02 + 0.02 + 0.01}{4} = \frac{0.06}{4}$$
$$\% \text{ error} = \frac{\Delta x_{mean}}{x_{mean}} = \frac{0.06}{4\times 1.21}\times 100 = \frac{150}{121}\%$$
Comparing above result with $\frac{x}{121}\%$, we get $x = 150$.

103. [5] $T = 0.5$ sec, No. of oscillation = 100
Resolution = 1sec, $\ell = 10$cm $\pm$ 1cm
$$T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow g = \frac{4\pi^2\ell}{T^2}$$
$$\frac{dg}{g}\times 100 = \frac{d\ell}{\ell}\times 100 + \frac{2dT}{T}\times 100$$
$$= \frac{0.1}{10}\times 100 + \frac{2}{50}\times 100 = 5\%, \text{ So, } x = 5$$

104. (*b*) $d_{av} = 5.5375$ mm
$\Delta d = 0.07395$ mm
ℓ Measured data are up to two digits after decimal
$\therefore d = (5.54 \pm 0.07)$ mm

105. (*c*)
$$\frac{\Delta Y}{Y} = \left(\frac{\Delta m}{m}\right) + \left(\frac{\Delta g}{g}\right) + \left(\frac{\Delta M}{\lambda}\right) + \left(\frac{\Delta l}{l}\right) + \left(\frac{\Delta L}{L}\right)$$
$$= \left(\frac{1g}{1kg}\right) + 0 + 2\left(\frac{\Delta r}{r}\right) + \left(\frac{\Delta l}{l}\right) + \left(\frac{\Delta L}{L}\right)$$
$$= \left(\frac{1g}{1kg}\right) + 2\left(\frac{0.001cm}{0.2cm}\right) + \left(\frac{0.001cm}{0.5cm}\right) + \left(\frac{0.001m}{1m}\right)$$
$$= \frac{1+10+2+1}{1000} = \frac{14}{1000}\times 100\% = 1.4\%.$$

106. (*b*) Here, time period of oscillation,
$$T = 2\pi\sqrt{\frac{L}{g}}$$
$$\Rightarrow T^2 = 4\pi^2\left(\frac{L}{g}\right) \Rightarrow g = 4\pi^2\left(\frac{L}{T^2}\right)$$
$$\therefore \frac{\Delta g}{g}\% = \left(\frac{\Delta L}{L} + \frac{2\Delta T}{T}\right)\%$$
$$= \left[\frac{1mm}{1m} + \frac{2\times 0.01}{1.95}\right]\times 100\%$$
$$= (0.001 + 0.0102)\times 100 = 1.13\%$$

107. (*a*) $V = IR = I\frac{\rho\ell}{\frac{\pi d^2}{4}} \Rightarrow \rho = \frac{\pi d^2 V}{4\ell I}$
So, $\frac{\Delta\rho}{\rho} = 2\cdot\frac{\Delta d}{d} + \frac{\Delta V}{V} + \frac{\Delta\ell}{\ell} + \frac{\Delta I}{I}$
$$= 2\times\frac{0.01}{5.00} + \frac{0.1}{5.0} + \frac{0.1}{10.0} + \frac{0.01}{2000} = 0.039$$
Percentage error $= \frac{\Delta\delta}{\delta}\times 100 = 3.9\%$

108. (*a*) Initial resistance, $R_i = \frac{r\ell}{A}$, $\ell_f = 1.25\ell$
As volume of wise will remain same.
$$A_f = \frac{A}{1.25}$$
Final resistance,
$$R_f = \frac{\rho(1.25\ell)}{(A/1.25)} = (1.25)^2\times\frac{\rho\ell}{A}$$
$R_f = 1.5625\ 5\ R_i$
% change in resistance
$$= \frac{R_f - R_i}{R_i}\times 100 = 56.25\%$$

109. [1] Time period of pendulum
$$T = 2\pi\sqrt{\frac{\ell}{g}}$$
$$\therefore g = 4\pi^2\frac{\ell}{T^2}$$
Percentage error in g,
$$\frac{\Delta g}{g} = \frac{\Delta\ell}{\ell} + \frac{2\Delta T}{T} = \frac{\Delta\ell}{\ell} + \frac{2\Delta T_0}{nT}$$
(Where ΔT_0 is least count for time and h is number of oscillation) From the given table it is clear that student - 1 will get least error.

110. (*b*) $T = 2\pi\sqrt{\frac{l}{g}}$
$$\Rightarrow \frac{\Delta T}{T}\times 100 = \frac{1}{2}\frac{\Delta l}{l}\times 100 + \frac{1}{2}\frac{\Delta g}{g}\times 100$$
[As $\Delta g = 0$]
$$\frac{\Delta T}{T}\times 100 = \frac{1}{2}\times 0.1 = 0.05\%$$
For 1 day $\Delta T = \frac{0.05}{100}\times 24\times 3600$
$\Delta T = 43.2$ sec

111. (*b*)
$$T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T^2 = 2\pi\left(\frac{l}{g}\right) \Rightarrow g = 2\pi\frac{l}{T^2}$$
$$\Rightarrow \frac{\Delta g}{g} = \frac{\Delta l}{l} + \frac{2\Delta T}{T}$$
$$\Rightarrow \frac{\Delta g}{g} = \frac{1\times 10^{-3}}{1\times 10^{-2}} + \frac{2\times 1}{100}$$
$$\Rightarrow \frac{\Delta g}{g} = 0.02 + 0.01 = 0.03$$
$$\Rightarrow 100\times\frac{\Delta g}{g} = 0.03\times 100 = 3\%$$

112. (*b*)
$$\left(\frac{\Delta y\times 100}{y}\right) = \left[2\times\frac{\Delta m}{m} + \frac{4\times\Delta r}{r} + \frac{x\times\Delta g}{g} + \frac{3}{2}\times\frac{\Delta\ell}{\ell}\right]\times 100$$
$\Rightarrow 18 = (2 \times 1) + (4 \times 0.5) + (xp) + \left(\frac{3}{2}\times 4\right) \Rightarrow 8 = xp$
Using given options
$\Rightarrow x = \frac{16}{3}; p = \pm\frac{3}{2}$

113. (*b*) $Y = \frac{MgL^3}{4bd^3\delta}$
$$\frac{\Delta Y}{Y} = \frac{\Delta M}{M} + \frac{3\Delta L}{L} + \frac{\Delta b}{b} + 3\frac{\Delta d}{d} + \frac{\Delta\delta}{\delta}$$
$$= \frac{1\times 10^{-3}}{2} + \frac{3\times 10^{-3}}{1} + \frac{10^{-2}}{4} + 3\times\frac{0.01\times 10^{-1}}{0.4} + \frac{10^{-1}}{5}$$
$$= 10^{-3}\left[\frac{1}{2} + 3 + \frac{1}{0.4} + \frac{3}{0.4} + \frac{1}{0.5}\right] = 0.0155$$

@RAJ CBSE X @RAJ_EDUNET

114. [14] $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow l = \frac{T^2 g}{4\pi^2}$

$E = mgl\frac{\theta^2}{2} = mg^2\frac{T^2 g^2}{8\pi^2}$

$\Rightarrow \frac{\Delta E}{E} = 2\left(\frac{\Delta g}{g} + \frac{\Delta T}{T}\right) = 2(4+3) = 14\%$

115. [5]

$\varepsilon_v = \frac{2}{50}\times 100 = 4\%,\ \varepsilon_l = \frac{0.2}{20}\times 100 = 1\%$

$\therefore \varepsilon_R = \pm(\varepsilon_v + \varepsilon_l) = \pm(4\% + 1\%) = \pm 5\%$

116. [34] We know that, volume of sphere,

$V = \frac{4\pi}{3}r^3 \Rightarrow \frac{\Delta V}{V} = 3\frac{\Delta r}{r}$

% error in volume $= \frac{\Delta V}{V}\times 100 = 3\frac{\Delta r}{r}\times 100$

$= 3\times\frac{0.85}{7.50}\times 100 \approx 34$

117. (a) $\frac{\Delta T}{T} = \frac{1}{2}\left(\frac{\Delta g}{g} + \frac{\Delta L}{L}\right)$

$\frac{\Delta g}{g} = \frac{2\Delta T}{T} + \frac{\Delta L}{L};\ = 2\left(\frac{1}{50}\right) + \frac{0.1}{25.0} = 4.4\%$

118. (b) $\frac{\Delta z}{z} = 2\frac{\Delta a}{a} + \frac{2}{3}\frac{\Delta b}{b} + \frac{1}{2}\frac{\Delta c}{c} + 3\frac{\Delta d}{d}$

$= 2\times 2 + \frac{2}{3}\times 1.5 + \frac{1}{2}\times 4 + 3\times 2.5 = 14.5\%$

119. (c) $\rho = \frac{m}{\frac{4}{3}\pi\left(\frac{d}{2}\right)^3}$

$\therefore \%\ \frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + 3.\left(\frac{\Delta d}{d}\right)$

$= 6 + 3\times 1.5 = 10.5\%$

120. (*) As the error is larger in length measurement. So to find the error in density measurement.

$\rho_{min} = \frac{m_{min}}{V_{max}} = \frac{9.9}{(0.11)^2} = 7438\ kg/m^3$

$\rho_{max} = \frac{m_{max}}{V_{min}} = \frac{10.1}{(0.09)^3} = 13854.6\ kg/m^3$

$\therefore \Delta\rho = 13854.6 - 7438 = 6416.6\ kg/m^3$

(Bonus)

121. (c) In case of simple pendulum,

$T = 2\pi\sqrt{\frac{L}{g}} \ \therefore g = \frac{4\pi^2 L}{T^2}$

% error in g

$= \frac{\Delta g}{g}\times 100 = \left(\frac{\Delta L}{L} + \frac{2\Delta T}{T}\right)100\%$

$= \left(\frac{0.1}{55} + \frac{2\left(\frac{1}{20}\right)}{\frac{30}{20}}\right)100\% \approx 6.8\%$

122. (c) $V = \pi R^2 h = \frac{\pi}{4}D^2 h = 4260\ cm^3$

$\because \frac{\Delta V}{V} = 2\frac{\Delta D}{D} + \frac{\Delta h}{h}$

$\Delta V = \left(2\times\frac{0.1}{12.6} + \frac{0.1}{34.2}\right)V$

$= \frac{2\times 426}{12.6} + \frac{426}{34.2}$

$= 67.61 + 12.459 = 80.075$

$\therefore V = 4260 \pm 80\ cm^3$

123. (c) $R_2 = (1.005)^2 R_1$

$\%\ \varepsilon_R = \frac{R_2 - R_1}{R_1}\times 100 = 1\%$

124. (b) $(n+1)$ VSD $= n$ MSD

$\Rightarrow 1VSD = \frac{n}{n+1}MSD$

$\Rightarrow L.C = 1\ MSD - 1\ VSD$

$L\cdot C = m - m\left(\frac{n}{n+1}\right)$

$= m\left(\frac{n+1-n}{n+1}\right)$

$\Rightarrow L\cdot C = \left(\frac{m}{n+1}\right)$

125. (b) Least count of the screw gauge

$= \frac{1}{100}mn = 0.01mn$

zero error $= +0.05$ mm

Reading $= 4\times 1$ mm $+ 60\times 0.01$ mm $-$ $0.05 = 4.55$ mm

126. (b) Least count of vernier calipers

$= \frac{1}{20N}cm$

ℓ Least count $= 1$ MSD $- 1$VSD

let x no. of divisions of main scale coincides with N division of vernier scale, then

$1\ VSD = \frac{x\times 1mm}{N}$

$\therefore \frac{1}{20N}cm = 1mm - \frac{x\times 1mm}{N}$

$\frac{1}{2N}mm = 1mm - \frac{x}{N}mm \Rightarrow x = \frac{2N-1}{2}$

127. (d) Here, 9MSD = 10VSD and mass = 8.635 g

For least count we have,

$LC = 1\ MSD - 1\ VSD$

$LC = 1MSD - \frac{9}{10}MSD = \frac{1}{10}MSD$

$LC = 0.01$ cm

Reading of diameter = MSR + LC × VSR

$= 2$ cm $+ (0.01)\times(2)$

$= 2.02$ cm

Volume of sphere

$= \frac{4}{3}\pi\left(\frac{d}{2}\right)^3 = \frac{4}{3}\pi\left(\frac{2.02}{2}\right)^3$

$= 4.32\ cm^3$

Density

$= \frac{\text{mass}}{\text{volume}} = \frac{8.635}{4.32} = 1.998 \sim 2.00\ g$

128. (c) Since, 4th division coincides with 3rd division then

0.004 cm $= 4$VSD $- 3$MSD (1)

& $1\text{MSD} = \frac{1}{N}$cm (2)

$49\text{MSD} = 50\text{VSD}$ (3)

$0.004 = 4\left\{\frac{49}{50}\text{MSD}\right\} - 3\ \text{MSD}$

$N = \frac{46}{50}\times\frac{1000}{4} = \frac{46\times 1000}{200} = 230$

129. (a) $1\ \text{MSD} - \frac{49}{50}\ \text{MSD}$

$= \frac{1\text{cm}}{20} - \frac{49}{50}\times\frac{1\text{cm}}{20}$

$= 0.001$ cm

LC $= 1$MSD$- 1$VSD $= 0.001$ cm

For mark on paper, $L_1 = 8.45$ cm $+$ 26×0.001 cm $= 84.76$ mm

For mark on paper through slab, L_2 $= 7.12$ cm $+ 41\times 0.001$ cm $= 71.61$ mm

For powder particle on top surface. ZE $= 4.05$ cm $+1\times 0.001$ cm $= 40.51$ mm

$\therefore$ actual $L_1 = 84.76 - 40.51$

$= 44.25$ mm

actual L2 $= 71.61 - 40.51$

$= 31.10$ mm

$L_2 = \frac{L_1}{\mu}$

refractive index $= \frac{44.25}{31.10} = 1.42$

130. (b) $LC = \frac{\text{pitch}}{\text{No. of CSD}} = \left(\frac{1}{100}\right)$

$= 0.01$ mm

Diameter $= MSR + LC\times CSD$

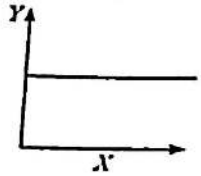
Diameter $= 1 + (0.01)\times 42$ mm

Therefore, $\frac{x}{50} = 1.42$

$\therefore x = 71$

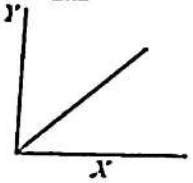
@TAKE_CBSE_X @RAJ_EDUNET

131. (a) Magnetic susceptibility Y and magnetising field X:



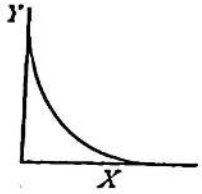
(B) For $x < a$:

$$B = \frac{\mu_0 ir}{2\pi a^2}$$

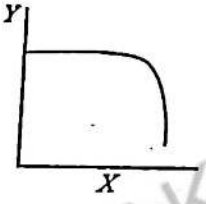


(C) For $x > a$:

$$B = \frac{\mu_0 i}{2\pi a}$$



(D) Variation of magnetic field inside solenoid:



132. (d) Given: 10 MSD = 11 VSD

$$\Rightarrow 1\text{VSD} = \frac{10}{11}\text{MSD}$$

As, LC = 1MSD – 1VSD

$$= 1\text{MSD} - \frac{10}{11}\text{MSD} = \frac{1\text{MSD}}{11}$$

$$= \frac{5}{11} \text{ units}$$

133. (d) $50\,V + S = 49S + S$

$S = 50\,(S - V)$

$0.5 = 50\,(S - V)$

The Vernier constant of travelling microscope is

$$S - V = \frac{0.5}{50} = \frac{1}{100} = 0.01\text{mm}$$

134. (b) Spherometer is an instrument that can be used to measure curvature of surface.

135. (b)

136. (a) ℓ Zero Error = 6 × Least Count

= 0.6 mm

∴ Reading = MSR + VSR × LC - Zero Error

= [32 mm + (0.1)4mm] – 0.6 mm

= 31.8 mm = 31.8×10^{-1} cm = 3.18 cm

= 3.18 cm

137. (b) 1 light year = 9.46×10^{15}m

1 parsec = 3.08×10^{16} m

1Au = 1.496×10^{11}m

Therefore, Au < ly < Parsec

138. [220] Least count

$$= \frac{\text{Pitch}}{\text{No. of circular divisions}} = \frac{0.5 \text{ mm}}{100}$$

$= 5 \times 10^{-3}$ mm

Positive Error = MSR + CSR (LC)

$= 0 \text{ mm} + 6\left(5 \times 10^{-3} \text{ mm}\right)$

Reading of Diameter = $MSR + CSR\,(LC)$ – Positive zero error

$= 4 \times 0.5 \text{ mm} + (46(5 \times 10^{-3})) - 6(5 \times 10^{-3})\text{mm}$

$= 2 \text{ mm} + 40 \times 5 \times 10 - 3 \text{ mm} = 2.2 \text{ mm}$

139. (c) 1 M.S.D. = 1 mm

Now, 9 M.S.D. = 10 V.S.D.

1 V.S.D. = 0.9 M.S.D. = 0.9 mm = 0.01 cm

Now, L.C. of vernier caliper = 1 – 0.9 = 0.1 mm = 0.01 cm

zero error = –(10 – 4) × 0.1 mm –0.6 mm

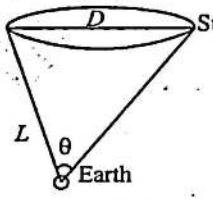
Reading = M.S.R + V.S.R – Zero error

= 3 cm + 6 × 0.01 – [–0.06]

= 3 + 0.06 + 0.06

= 3.12 cm ~ nearest to 3.10

140. (c) Given, radius, r = 1.5×10^{11} m



θ = 2000 seconds [ℓ 1° = 60°, 1' = 60"]

$$= \frac{2000}{60 \times 60}\text{degree} = \frac{2000}{60 \times 60} \times \frac{\pi}{180}\text{radian}$$

$$= \frac{\pi}{36 \times 9}\text{radian}$$

Formula, Angle (θ) = $\frac{\text{Arc}}{\text{radius}}$

$$\theta = \frac{D}{r} \Rightarrow D = \theta \cdot r \qquad [\text{arc} \approx D]$$

$$= \frac{\pi}{36 \times 9} \times 1.5 \times 10^{11} = 1.45 \times 10^{9} \text{ m}$$

141. (c) MSD = 20 divisions per cm ⇒ 1 MSD

$$= \frac{1}{20} cm$$

$$1VSD = \frac{24}{25} MSD \text{ , } L.C. = 1\ MSD - 1VSD$$

$$= 1MSD - \frac{24}{25} MSD = \frac{1}{25} \times \frac{1}{20} cm = 0.002\,cm$$

142. (a) L.C. = $\frac{0.5}{50}$ mm = 0.01 mm

$d = (2.5 + 45 \times 0.01)$ mm = 2.95 mm

143. [180] We have given, main scale reading = 1.7 cm

Zero correction = 0.05 cm

Vernier scale reading = 5 × 0.1 = 0.5 mm

Diameter of sphere = Main scale reading + Vernier scale reading + Zero correction

= 1.7 + 0.05 + 0.05 = 1.8 cm = 180×10^{-2} cm.

144. [412] 1MSD = 1mm

10VSD = 9MSD

Therefore, 1VSD = 0.9 MsD

L.C = 1MSD – 1VSD = 1 – 0.9 = 0. 1mm

Positive zero error = 4LC = 0.4 mm

Reading = MSR + VSR + correction

= 4.1 cm + 6 × .01cm + (–0.04cm)

= 4.12cm = 412 × 10^{-2}cm

145. [5] Let x be the value of one division of main scale

$$\therefore x = \frac{1}{20} \text{ cm} = 0.05 \text{ cm}$$

Let y be value of one division on vernier scale

$$10y = 9x \Rightarrow y = \frac{9x}{10}$$

$$\text{Least count} = x - \frac{9x}{10} = \frac{x}{10} = \frac{0.05}{10}$$

$= 0.005$ cm $= 5 \times 10^{-2}$ mm

146. (b) $\text{L.C} = \frac{\text{Pitch}}{\text{No. of division on circular scale}}$

$$= \frac{0.5}{50}\text{mm} = 0.01\text{mm}$$

Diameter, $d = 1.5 + 7 \times 0.01$

= 1.57 mm = 0.157 cm

∴ Curved Surface Area = $(2\pi r)\ell = \pi d\ell$ (ℓ $d = 2r$)

$= 3.142 \times 0.157 \times 6.8 = 3.354 \text{ cm}^2 = 3.4 \text{ cm}^2$

147. (b) Number of divisions = 50, Pitch = 0.5mm

$$\text{L.C} = \frac{0.5 \text{ mm}}{50} = 0.01 \text{ mm}$$

True Reading = 5mm + 20 × 0.01 – 5 × 0.01 = 5.15 mm

148. (b) Reading = $MSR + VSD \times LC$ – zero error

$$\text{Reading} = 8.5 + \frac{(0.1) \times 6}{10} - \frac{0.2}{10} = 8.54 \text{ cm}$$

@FAKE_CBSE_GRAJ_EDUNET

$\Rightarrow 1 = 100 \times \frac{4}{3}\pi \times \frac{3}{40\pi} \times 10^{-9} \times 0.01$

$= 2.5 \times 10^{-11}$ cm $= 25 \times 10^{-14}$ m.

150. (a) $LC = \frac{\text{Pitch}}{\text{No. of division}} = \frac{1}{100}$ mm

$= 0.01$ mm

Zero error $= +0.08$ mm.

Diameter $= 1 + 72 \times 0.01 - 0.08 = 1.64$ mm

Radius $= 0.82$ mm

151. (b) Least count

$= \frac{\text{Pitch}}{\text{Total divisions on circular scale}}$

$\therefore$ 5 revolution, distance travelled $= 5$ mm

$\therefore$ 1 revolution, distance travelled $= 1$ mm

$\therefore L.C. = \frac{1}{50} = 0.02$ mm $= 0.002$ cm

Therefore, Assertion is not correct but reason is correct

152. (c) $(n-1)MSD = nVSD$

$\Rightarrow VSD = \frac{n-1}{n}(MSD)$

Now, $LC = [1\ MSD - 1VSD]$ cm

$= a - \frac{n-1}{n}a = \frac{a}{n}$ cm $= \left(\frac{10a}{n}\right)$ mm

153. [52] Given: 9 MSD = 10 VSD

Least count of vernier = 1 MSD − 1 VSD

$= 1MSD - \frac{9}{10}$

MSD $= 0.1MSD = 0.1 \times 1$ mm $= 0.1$ mm

Reading $= 10$ mm $+ 8 \times 0.1$ mm $= 10.8$ mm

Final reading $= 10.8$ mm $- 0.04$ mm $= 10.4$ mm

So, radius of bob $= 5.2$ mm $= 52 \times 10^{-2}$ cm

154. [13] Difference in Reading

= Positive Zero Error − Negative Zero Error

$= (+5) - [-(100 - 92)] = 13$

155. (c) Given 10 $VSD = 9$ MSD

Least count $= 1\ VSD = \frac{9}{10}\ MSD$

Least count $= 1\ MSD - 1\ VSD = \left(1 - \frac{9}{10}\right)$ MSD

$= 0.1\ MSD = 0.1 \times 0.1$ cm $= 0.01$ cm

As '0' of V.S. lie before '0' of M.S.

Zero error $= -[10 - 6]$ L.C.

$= -4 \times 0.01$ cm $= -0.04$ cm

Reading $= 3.1$ cm $+ 1 \times$ LC

$= 3.4$ cm $+ 1 \times 0.01$ cm $= 3.11$ cm

True diameter = Reading − Zero error

$= 3.11 - (-0.04)$cm $= 3.15$ cm

156. (b) Least count $= \frac{0.5\text{ mm}}{50}$

$= 1 \times 10^{-5}$ m $= 10\mu$m

157. (*) $\Lambda_1 + B_1 + C_1$

$= 24.36 + 0.0724 + 256.2$

$= 280.6324$

$\Lambda_2 + B_2 + C_2$

$= 24.44 + 16.082 + 240.2$

$= 280.722$

$A_3 + B_3 + C_3 = 25.2 + 19.2812 + 236.183$

$= 280.6642$

$A_4 + B_4 + C_4 = 25 + 236.191 + 19.5$

$= 280.691$

So, no option is correct. (Bonus)

158. (c) Least count $= \frac{p}{N} = \frac{0.1\text{ cm}}{50} = 0.02$ mm

$= 0.002$ cm

Hence, measurement should integral multiple of LC.

159. (b) Least count

$= \frac{\text{Pitch}}{\text{No. of divisions on circular scale}}$

$\Rightarrow 5 \times 10^{-6} = \frac{10^{-3}}{N} \Rightarrow N = 200$

JEE-Advanced

1. (c) The velocity v any point of the surface of the expanding sphere is proportional to R.

The density is given as

$\rho = \frac{\text{Mass}}{\text{Volume}}$

Mass $= \rho \times$ volume $=$ constant

On differentiating,

$\Rightarrow V\frac{d\rho}{dt} + \rho\frac{dV}{dt} = 0$

$\Rightarrow \frac{4}{3}\pi R^3 \times \frac{d\rho}{dt} + \rho \times \frac{d}{dt}\left(\frac{4}{3}\pi R^3\right) = 0$

$\Rightarrow \frac{1}{\rho}\frac{d\rho}{dt} = \frac{-3}{R}\frac{dR}{dt} =$ Constant

$\Rightarrow \frac{dR}{dt} =$ constant $\times R$

$\frac{dR}{dt} \propto R$

2. (c) The general relation among vectors P, Q and S is $\vec{S} = (1-b)\vec{P} + b\vec{Q}$.

From triangular law of vector addition, we get $\overrightarrow{OP} + \overrightarrow{PS} = \overrightarrow{OS}$

$\therefore \vec{P} + b|\vec{R}|\frac{\vec{R}}{|\vec{R}|} = \vec{S}$

$\vec{P} + b\vec{R} = \vec{S}$

But $\vec{R} = \vec{Q} - \vec{P}$ (Given)

$\vec{P} + b(\vec{Q} - \vec{P}) = \vec{S}$

$\Rightarrow \vec{S} = (1-b)\vec{P} + b\vec{Q}$

3. (a) Given: Length of the cube,

$L = 1.2 \times 10^{-2}$ m

We know, Volume of the cube,

$V = L^3 = (1.2 \times 10^{-2}) \times (1.2 \times 10^{-2}) \times (1.2 \times 10^{-2})$ m^3

$\Rightarrow V = 1.728 \times 10^{-6}$ m^3

But as the length contains only 2 significant digits, the volume must also contain 2 significant digits. Hence, volume of the cube is 1.7×10^{-6} m^3.

4. (A) The dimensions of the magnetic flux and rigidity modulus in terms of mass, length, time and charge are $[\phi] = [M^1L^2T^{-1}Q^{-1}]$ and $[n] = ML^{-1}T^{-2}$.

Dimension of magnetic field, $[B] = [M^1L^0Q^{-1}]$ and Dimension of surface Area, $[A] = [L^2]$.

The magnetic flux is given as the product of the magnetic field and surface area; $\phi = B.A$.

The dimension of magnetic flux in term of mass, time, length and charge, $[\phi] = [M^1L^2T^{-1}Q^{-1}]$

(B) Shear stress $= \eta$ (Shear strain), where, η = modulus of rigidity

According to the formula, we get the dimensions of 'η' same as that of pressure as of shear strain is dimensionless.

$\therefore [\eta] = ML^{-1}T^{-2}$

5.

1. Young's modulus $= Nm^{-2} =$ Newton per meter^2
2. Magnetic induction $= W \cdot m^{-2} =$ Tesla
3. Power of lens $= m^{-1} =$ diopter

6. (b,d)

$\vec{S} = [\vec{E} \times \vec{B}]\frac{1}{\mu_0}$

@TAKE_CBSE_X @RAJ_EDUNET

$\vec{S}$ is pointing vector denotes flow of energy per unit area per unit time

$$\vec{S} = \frac{\text{watt}}{m^2}$$

7. (*a,c,d*)

Using the formula of emf;

$$e = \frac{d\phi}{dt} = L\frac{dI}{dt}$$

$$\Rightarrow [\text{volt}] = \frac{[\text{weber}]}{[\text{second}]} = [L]\frac{[\text{ampere}]}{[\text{second}]}$$

And Energy dissipated (E) = VIt

Putting the units of all the above values,

$\Rightarrow$ [Joule] = [volt][Ampere][second]

$$\Rightarrow [\text{volt}-\text{second}] = \frac{[\text{Joule}]}{[\text{Ampere}]}$$

Thus, we can now evaluate the unit of self inductance, units of self inductance L is,

$$[L] = \frac{\text{weber}}{\text{Ampere}} = \frac{\text{volt}-\text{second}}{\text{Ampere}} = \frac{\text{Joule}}{\text{Ampere}^2}$$

d also correct

$$\frac{1}{2}Li^2 = i^2Rt \Rightarrow [L] = [Rt] = Ohm - \text{sec}$$

8. A-p,q B-r,s C-r,s D-r,s

Given: G is the universal gravitational constant, R is the universal gas constant, T is the absolute temperature and B is the magnetic field.

(A) GM_eM_s where, M_e is the mass of the earth and M_s is the mass of the Sun.

From the Gravitational force formula,

$GM_eM_s = Fr^2$

Taking the units of each value and deriving its dimensions:

SI unit of Force is (kilogram) (metre) s^{-2}.

SI unit of r^2 is m^2.

$$= Nm^2\,kg\frac{m}{s^2} \times m^2 = kgm^3s^{-2}$$

Also, (volt) (coulomb) (meter) has the same dimensions.

(Joule) (meter)

$$= kg\left(\frac{m}{s^2}\right)\cdot m\cdot m \Rightarrow \frac{dn}{N} = -td$$

$$= \left(1-\frac{9}{10}\right)\times 1mm = \text{kg m}^3\,\text{s}^{-2}$$

(B) $\frac{3RT}{M}$ where, R is the universal gas constant, T is the absolute temperature.

Taking root mean square velocity formula:

$$v_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow v_{rms}^2 = \frac{3RT}{M}$$

Unit of $\frac{3RT}{M}$ is m^2s^{-2}

Also, (farad) (volt)^2 (kg)$^{-1}$ has the same dimensions.

(farad) (volt)^2 (kg)$^{-1}$

= (Joule) (kg)$^{-1}$

$$= \text{kg}\left(\frac{m}{s^2}\right)\cdot\text{m (kg)}^{-1}$$

$$= \text{m}^2\,5^{-2}$$

(C) $\frac{F^2}{q^2B^2}$

Force in the magnetic field;

$$F = qvB \Rightarrow v^2 = \frac{F^2}{q^2B^2}$$

unit of v^2 is m^2s^{-2} which is also equal to FJ/kg^{-1}.

Hence, (farad) (volt)^2 (kg)$^{-1}$ has the same dimensions:

(D) $\frac{GM_e}{R_e}$

We know, Escape velocity,

$$V_e = \sqrt{\frac{2GM}{R}} \Rightarrow V_e^2 = \frac{2GM}{R}$$

So the unit of $\frac{GM}{R}$ is m^2s^{-2}

9. Let us first derive Capacitance, Inductance and Magnetic Induction in terms of given units.

Capacitance is the charge per unit volt.

And we know, Volt has unit of work per unit charge.

So capacitance has units of charge square per unit energy.

Inductance is defined as volt per unit rate of change of current and voltage per unit current is resistance, so inductance is ohm second.

Magnetic Induction is defined as the property of the material by which it gets magnetized by an external magnetic field.

Equation for magnetic induction:

For a moving rod, $N = 1$ and the flux $\Phi = BA\cos\theta$, $\theta = 0°$, and $\cos\theta = 1$, a B is perpendicular to A.

10. $A = a\hat{i}$ and $B = a\cos\omega\hat{i} + a\sin\omega t\,\hat{j}$

$$A + B = (a + \cos\omega t)\hat{i} + \sin\omega t\,\hat{j}$$

$$A - B = (a - \cos\omega t)\hat{i} + a\sin\omega t\,\hat{j}$$

$$|A + B| = \sqrt{3}\ |A - B|$$

$$\sqrt{(a+a\cos\omega t)^2 + (a\sin\omega t)^2} = \sqrt{3}\sqrt{(a+a\cos\omega t)^2 + (a\sin\omega t)^2}$$

$$\Rightarrow 2\cos\frac{\omega t}{2} = \pm\sqrt{3}\times 2\sin\frac{\omega t}{2}$$

$$\Rightarrow \tan\frac{\omega t}{2} = \pm\frac{1}{\sqrt{3}}$$

$$\Rightarrow \frac{\omega t}{2} = n\pi \pm \frac{\pi}{6} \Rightarrow \frac{\pi}{12}t = n\pi \pm \frac{\pi}{6}$$

$$\Rightarrow t = (12n \pm 2)\text{s} = 2\text{s}, 10\text{s}, 14\text{s and so on.}$$

11. (*d*) Dipole moment, electric flux and electric field have different sets of dimensions.

The dimensions of the dipole moment, electric flux and electric field are given as;

Electric Dipole moment = Charge × distance between the charges = $[AT] \times [L] = [ALT]$

Electric flux = field strength × area = $[MLT^{-3}A^{-1}][L^2] = [ML^2T^{-3}A^{-1}]$

And Electric field = Force per unit charge = $[MLT^{-3}A^{-1}]$

Since, all have different dimensions.

12. (*a*) The dimensional formula for β will be $[M^1L^2T^0]$

Given: The given relation:

$p = \frac{\alpha}{\beta}e^{-\left(\frac{\alpha z}{k\theta}\right)}$, where p is the pressure, k is the Boltzmann's constant and θ is the temperature.

In given equation, $\frac{\alpha z}{k\theta}$ should be dimensionless

$$\therefore \alpha = \frac{k\theta}{z}$$

$$\Rightarrow \alpha = \frac{ML^2T^{-2}K^{-1}\times K}{L} = MLT^{-2}$$

And $p = \frac{\alpha}{\beta}$

Now, the dimension for β is given as:

$$\Rightarrow \beta = \frac{\alpha}{p} = \frac{MLT^{-2}}{ML^{-1}T^{-2}} = M^0L^2T^0$$

13. (*d*) The dimensional formula for X is the same as that of Current.

Given: X is given as $\varepsilon_0 L\frac{\Delta V}{\Delta t}$, where, ε_0 is the permittivity of free space, L is a length, ΔV is a potential difference and Δt is a time interval.

Dimensional formula for $\varepsilon_0 = [M^{-1}L^{-3}T^4I^2]$

Dimensional formula for $L = [L]$

Dimensional formula for $\Delta V = [ML^2T^{-3}I^{-1}]$

Dimensional formula for $\Delta t = [T^1]$

Therefore, dimensional formula for X is:

Therefore, it's the same as that of current.

14. (*c*) Given: ε_0 is the permittivity of free space and E is the given electric field.

Taking the dimensions of Electric field and permittivity of space;

Dimension of ε_0 : $M^{-1}L^{-3}T^4A^2$

Dimension of E (Electric field)

$= MLT^{-2}/AT = MLT^{-3}A^{-1}$

Dimension of

$$\left[\frac{1}{2}\varepsilon_0E^2\right] = [M^{-1}L^{-3}T^4A^2][MLT^{-3}A^{-1}]$$

$$= ML^{-1}T^{-2}$$

DRAKE_CBSE_@RAJ_EDUNET

15. (*b*) The dimensional formula for the permittivity of vacuum is $[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2]$.
Given: Mass, length, time and electric current are M, L, T and A.
We can find the dimensional formula of the permittivity of free space using the force formula from Coulomb's law;

Using Coulomb law, $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{R^2}$

$\Rightarrow \varepsilon_0 = \frac{q_1q_2}{4\pi FR^2}$

Substituting the units in the equation:

So, $\varepsilon_0 = \frac{C^2}{N \cdot m^2}$

$= \frac{[AT]^2}{MLT^{-2} \cdot L^2} = \left[M^{-1}L^{-3}T^4A^2\right]$

16. (*b,d*) $l = \sqrt{\left(\frac{Ek_ET}{nq^2}\right)}$ and $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{1/3}k_BT}\right)}$ are the correct dimensions.
Given: (ε) is the permittivity of a dielectric material, (k_B) is the Boltzmann constant (T) is the absolute temperature, n is the number of particles per unit volume and q is the charge on the particle.
The general dimension for the expression of length is given as;

$\left[\frac{\varepsilon_0k_BT}{q^2}\right] = \left[\frac{q^2}{Fr^2}\frac{Fr}{q}\right] = \left[\frac{1}{r}\right] = [L^{-1}]$

$\left[\frac{q^2}{\varepsilon_0k_BT}\right] = [L]$, where length is written in terms of all the given values.
Now, solving options (*a*), (*b*), (*c*) and (*d*) one by one:

Option (*a*): $\left[\sqrt{\frac{nq^2}{\varepsilon_0k_BT}}\right] = [\sqrt{L^{-3}L}] = [L^{-1}]$

Option (*b*): $\left[\sqrt{\frac{\varepsilon_0k_BT}{nq^2}}\right] = \left[\sqrt{\frac{L^{-1}}{L^{-3}}}\right] = [L]$

Option (*c*):

$\left[\sqrt{\frac{q^2}{\varepsilon_0k_BTn^{2/3}}}\right] = \left[\sqrt{\frac{L}{L^{-2}}}\right] = [L^{3/2}]$

Option (*d*):

$\left[\sqrt{\frac{q^2}{\varepsilon_0k_BTn^{2/3}}}\right] = \left[\sqrt{\frac{L}{L^{-1}}}\right] = [L]$

Here, The dimensionally correct expressions for length are options (*b*) and (*d*).

17. (*a; c, d*) $M \propto h^ac^bG^c$
$M^1 \propto (ML^2T^{-1})^a\,(LT^{-1})^b\,(M^{-1}L^3T^{-2})^c$
$\propto M^{a-c}L^{2a+b+3c}T^{-a-b-2c}$

$a - c = 1$ ...(*i*)
$2a + b + 3c = 0$ ...(*ii*)
$a + b + 2c = 0$ ...(*iii*)
On solving (*i*), (*ii*), (*iii*), we get

$a = \frac{1}{2}, b = +\frac{1}{2}, c = -\frac{1}{2}$

$\therefore$ $M \propto \sqrt{c}$ only $\rightarrow$ (*a*) is correct.
In the same way we can find that, $L \propto h^{1/2}c^{-3/2}G^{1/2}$

$L \propto \sqrt{h}$, $L \propto \sqrt{G}$ $\rightarrow$ (*c*), (*d*) are also correct.

18. (*a,c*) The dimensionally correct equations are $\mu_0I^2 = E_0V^2$ and $I = E_0cV$.
Given: V is the potential difference, I is the Current, ε_0 is the permittivity, μ_0 is the permeability of free space and c is the speed of light.
Dimensional formula of potential difference is;
$V = ML^2T^{-3}A^{-1}$
The dimensional formula for current is;
Current = A
$C = LT^{-1}$
The dimensional formulas for permittivity and permeability are;
$\mu_0 = MLT^{-2}A^{-2}$
$\varepsilon_0 = M^{-1}L^{-3}T^4A^2$
By equating equations we get,
$\mu_0I^2 = [M^1L^1T^{-2}]$ and $\varepsilon_0V^2 = [MLT^{-1}]$
$\mu_0I^2 = \varepsilon_0V^2 \rightarrow (i)$
Similarly,
$I = E_0cV \rightarrow (ii)$

19. (*b,c*) $[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2]$ and $[\mu_0] = [MLT^{-2}A^{-2}]$ are the correct dimensional formulas for $[\varepsilon_0]$ and $[\mu_0]$.
From coulomb's law,
Dimension formula of ε_0

$\varepsilon_0 = \frac{1}{4\pi F}\frac{q_1 \cdot q_2}{r^2}(F = MLT^{-2})$

$\varepsilon_0 = \frac{1}{MLT^{-2}}\frac{AT \times AT}{L^2}$

$= M^{-1}L^{-3}T^4A^2$

And for the permeability of the vacuum;

$C = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

Dimension of μ_0: $= \frac{1}{[\varepsilon_0][\mu_0]^2}$

$= \frac{1}{M^{-1}L^{-3}T^4A^2 \times \left(LT^{-1}\right)^2}$

$[\mu_0] = \left[MLT^{-2}A^{-2}\right] = \frac{1}{[\varepsilon_0][\mu_0]^2}C = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

20. (*a, b, c*)Reynolds number and the coefficient of friction has no dimensions, so option (*a*) is the correct answer.

Planck's constant and Torque do not have the same dimensions;
Planck's constant $[h] = ML^2T^{-1}$ and Torque $= ML^2T^{-2}$.
The dimensional formulas for Latent heat and gravitational potential are given as;

Latent heat $= \frac{\text{energy}}{\text{mass}} = \frac{M^1L^2T^{-2}}{M} = L^2T^{-2}$

Gravitational potential

$= \frac{GM}{r} = \frac{\text{force}}{\text{mass}} \times r = \frac{M^1L^1T^{-2}}{M^1} \times L^1$

$= L^2T^{-2}$

Since, there dimensions are same, option (*c*) is also correct.
Curie and frequency of a light wave both also have the same dimensions.
Curie = freq. $= M^0L^0T^{-1}$.

21. (*a,d*) Options (*a*) and (*d*) are the correct answers.
Defining all the terms:
Torque is the cross product of distance vector and force, whereas work is the dot product of both the distance vector and the force. Hence, their units are the same which is joule.
So, option (*a*) is correct.
Angular momentum is a product of distance from the rotation axis and linear momentum. So, its unit is kgm²/s whereas the unit of work is joule. So, the units are different.
Thus, option (*b*) is incorrect.
Unit of energy is the same as work which is joule. Whereas, Young's modulus is the ratio of force per unit surface and strain. So, its unit is N/m. Hence, the units of both are different
So, option (*c*) is incorrect.
For measuring larger distance in space, light year us used. Which can be measured into meters, kilometers, etc. Whereas, wavelengths of atoms are smaller for atoms which are generally measured in nanometers. Both can be converted into meters. So, dimensions and units are same for both.
So, option (*d*) is the correct answer.

22. (*a,b,c*) Options (*a*), (*b*) and (*c*) are correct.
The combinations of L, R and C which have the dimensions of frequency are given as:
For RC circuits, time is constant $\tau = RC$ has unit of time, and since time and frequency are related to each other, thus $\frac{1}{RC}$ has a unit of frequency, similarly for LC oscillations, $\tau = \sqrt{LC}$ for RL circuit $\tau = \frac{L}{R}$, in terms of resistance. Hence,
$\frac{1}{RC}$, $\frac{R}{L}$ and $\frac{1}{\sqrt{LC}}$ has units of frequency

@TAKE CREEK @RAJ PUNJET

23. A-(r), B-(u), C-(p), D-(t), E-(q), F-(s)
Given: The dimensions are expressed in terms of M, L, T and Q.

1. **Angular momentum:** It is defined as rotational movement given by moment of inertia and the angular velocity.
$L = mvr$
Where, L is the angular momentum, m is the mass, v is the velocity and r is the radius.
The dimensional formula for L is given as:
$[ML^1T^{-1}L^1] = [ML^2T^{-1}]$
2. **Latent Heat:** It is the hidden form of energy supplied to the body with its temperature constant.
$$\text{Latent Heart} = \frac{\text{Heat}}{\text{Mass}}$$
$$= \frac{ML^2T^{-2}}{M} = L^2T^{-2}$$
3. **Torque:** Force × Distance
$= F \times d = ML^1T^{-2} \cdot L = [ML^2T^{-2}]$
4. **Capacitance:**
$$C = \frac{Q}{V} = \frac{Q}{\frac{W}{Q}} = \frac{Q^2}{W} = \frac{Q^2}{ML^2T^{-2}}$$
$$= M^{-1}L^{-2}T^{-2}Q^2$$
5. **Inductance:** It is the property of the circuit by which it opposes the change in electric current flowing through it.
$$W = \frac{1}{2}LI^2$$
$$L = \frac{W}{I^2} = \frac{[ML^2T^{-2}]}{I^2} \quad |Q = IT|$$
$$= ML^2Q^{-2}$$
6. **Resistivity:** Resistivity is defined as the measure of the property of the material of how strongly it opposes the flow of current flowing through it.
$$\rho = \frac{RA}{I} = \left[\frac{ML^2T^{-2}.L^2}{Q^2.L}\right] = ML^3T^{-1}Q^{-2}$$

24. $[h] = ML^2T^{-1}$ is the dimension of Planck's constant.
The energy of a photon of radiation is given by $[E] = [h][v]$.
Now, by doing dimensional analysis on energy and frequency we get,
$[E] = [h][v]$
Substituting the values of dimensions of energy and frequency in the formula;
$ML^2T^{-2} = [h]T^{-1}$
$$\Rightarrow [h] = \frac{ML^2T^{-2}}{T^{-1}} \quad ...(i)$$
$$\Rightarrow [h] = ML^2T^{-1}$$

25. $\left[\frac{a}{V^2}\right] = [p]$
$\therefore \quad [a] = [pV^2] = [ML^{-1}T^{-2}][L^6] = [ML^5T^{-2}]$

26. The values of a, b and c are $a = \frac{-5}{6}, b = \frac{1}{2}$ and $c = \frac{1}{3}$.
During an explosion under water, we have-
Given time period T and the relation;
$T \propto P^a d^b E^c$
$T = kP^a d^b E^c$ ...(i)
where K is a constant of proportionality and dimensionless quantity.
Inserting the dimensions of Time, pressure, density and Energy in equation (i) we get
$[T] = [ML^{-1}T^{-2}]^a[ML^{-3}]^b[ML^2T^{-2}]^c$
Equating powers of M, L, T on both sides we get
$0 = a + b + c$ ...(ii)
$0 = -a - 3b + 2c$ ...(iii)
$1 = -2a - 2c$ ...(iv)
By solving (ii), (iii), (iv), we get;
$$a = \frac{-5}{6}, \; b = \frac{1}{2} \text{ and } c = \frac{1}{3}.$$

27. (a) $Y = c^\alpha h^\beta G^\gamma$
$[ML^{-1}T^{-2}] = [LT^{-1}]^\alpha[ML^2T^{-1}]^\beta[M^{-1}L^3T^{-2}]^\gamma$
$[ML^{-1}T^{-2}] = [M^{\beta-\gamma}][L^{\alpha+2\beta+3\gamma}][T^{-\alpha-\beta-2\gamma}]$
$1 = \beta - \gamma$ ...(i)
$-1 = \alpha + 2\beta + 3\gamma$ ...(ii)
$-2 = -\alpha - \beta - 2\gamma$ ...(iii)
After solving above equations
$\alpha = 7, \beta = -1, \gamma = -2$

28. (c) The relation between $[E]$ and $[B]$ is $[E] = [B][L][T]^{-1}$.
We know the relation between force, charge and electric field is:
$$\frac{F}{q} = E; \; F = qVB$$
Thus, the electric and magnetic field are related to each other as:
$\therefore E = BV$, hence the dimensions are:
$\Rightarrow [E] = [B][L][T]^{-1}$

29. (d) $[\mu_0] = [\varepsilon_0]^{-1}[L]^{-2}[T]^2$ is the correct relation between $[\varepsilon_0]$ and $[\mu_0]$.
The speed of light is,
Given by,
$$C = \frac{1}{\sqrt{\mu_0\varepsilon_0}}, \text{ where, } [\mu_0] \text{ is the}$$
permeability and $[\varepsilon_0]$ is the permittivity of free space.
$$\therefore [C^2] = \left[\frac{1}{\mu_0\varepsilon_0}\right] \Rightarrow L^2T^{-2} = \frac{1}{[\mu_0][\varepsilon_0]}$$
$$\Rightarrow [\mu_0] = [\varepsilon_0]^{-1}[L]^{-2}[T]^2$$

30. (c) Substituting the units:
$$[\omega_P] = [T]^{-1} = \left[\frac{1}{L^3}\right]^x [IT]^y [M]^z \left[\frac{I^2T^4}{ML^3}\right]^t \quad ...(i)$$
(As $[M] = \frac{1}{\angle 3}$ & [charge] = IT)
Also $[\varepsilon_0] = \frac{I^2T^4}{ML^3}$
Comparing the powers of M, L, I and T.
$z - t = 0$ ...(ii)
$-3x - 3t = 0$ ...(iii)
$y + 2t = 0$ ...(iv)
$y + 4t = -1$ ...(v)
Solving equations
$$y = 1; t = -\frac{1}{2}; z = -\frac{1}{2}; x = \frac{1}{2}$$
Substituting x, y, z and t in equation (i)
$$\omega_p = \frac{\sqrt{Ne}}{\sqrt{m}\sqrt{\varepsilon_0}} = \sqrt{\frac{Ne^2}{m\varepsilon_0}}$$

31. (b) Using formula;
$$\omega_p = \sqrt{\frac{Ne^2}{m\varepsilon_0}}$$
$$= \sqrt{\frac{4\times10^{27}\times(1.6\times10^{-19})^2}{10^{-30}\times10^{-11}}}$$
$$\omega_p = 1.6 \times 2 \times 10^{15}$$
$$f = \frac{\omega}{2\pi} = 0.5 \times 10^{15}$$
$$c = f\lambda$$
$$\lambda = \frac{3\times10^8}{0.5\times10^{15}} = 600\,\text{nm}$$

32. (a, b)
Given $L = x^\alpha$ ...(i)
$LT^{-1} = x^\beta$ ...(ii)
$LT^{-2} = x^p$ ...(iii)
$MLT^{-1} = x^q$ ...(iv)
$MLT^{-2} = x^r$ ...(v)
$$\frac{(i)}{(ii)} \Rightarrow T = x^{\alpha-\beta}$$
From (iii)
$x^\alpha T^{-2} = x^p$
$$\frac{x^\alpha}{x^{2(\alpha-\beta)}} = x^p$$
$\Rightarrow \alpha + p = 2\beta$
From (iv)
$M = x^{q-\beta}$
From (v) $x^{q-\beta}x^p = x^r$
$q - \beta + p = r$
$p + q - r = \beta$

33. (a,b,d) Mass $= M^0L^0T^0$
$Mvr = M^0L^0T^0$
$$M^0\frac{L^1}{T^1}.L^1 = M^0L^0T^0$$
$L^2 = T^1$
Force $= M^1L^1T^{-2}$ (in S
$= M^0L^1L^{-4}$
[In new system from equation (i
$= L^{-3}$
Energy $= M^1L^2T^{-2}$ (In S

@FAKE CBSE K @RAJEEV UNET

$= M^1L^2L^{-4} = L^{-2}$

[In new system from equation (*i*)]

Power $= \frac{\text{Energy}}{\text{Time}}$

$= M^1L^2T^{-3}$ (in *SI*)

$= M^1L^2L^{-6}$

[In new system from equation (*i*)]

$= L^{-4}$

Linear momentum $= M^1L^1T^{-1}$ (in *SI*)

$= M^1L^1L^{-2}$[In new system from equation(*i*)]

$= L^{-1}$

34. [3]

The value of n is 3.

Solving the above question step by step:

Step 1: As we don't know any relation between known [ρ, S, f] and unknown [d] quantity, let us take unknown on LHS and equate it with known on RHS, with each factor in product form and raised to some arbitrary powers say x, y and z.

Let,

$d = \rho^x \times S^y \times f^z$ ...(*i*)

Step 2: Express the data in its fundamental (base) quantity

Distance $[d] = [L]$

Density $[\rho] = [ML^{-3}]$

Intensity $[S] = [MT^{-3}]$

Frequency $[f] = [T^{-1}]$

Step 3: By equality of dimension analysis, dimensions on LHS should be equal to that in RHS;

$[L] = [ML^{-3}]^x[MT^{-3}]^y[T^{-1}]^z$

$[L] = [M^{x+y}][L^{-3x}][T^{-3y-z}]$ ... arranging

On equating LHS and RHS, we get,

$x + y = 0, -3x = 1, -3y - z = 0$

$x = \frac{-1}{3} \qquad y = \frac{1}{3} \qquad z = -1$

Substitution in (1) we get,

$d = \rho^{-1/3} \times S^{1/3} \times f^{-1}$

Step 4: Comparison with $S^{1/n}$ with $S^{1/3}$ gives:

$n = 3$

35. [4] $MT^{-2}I^{-1} = [IT]^\alpha[M]^\beta[ML^2T^{-1}]^\gamma[ML^3T^{-4}I^{-2}]^\delta$

$\therefore \beta + \gamma + \delta = 1$ ...(*i*)

$2\gamma + 3\delta = 0$ ...(*ii*)

$\alpha - \gamma - 4\delta = -2$ ...(*iii*)

$\alpha - 2\delta = -1$ ...(*iv*)

On solving these equations, we get

$\alpha + \beta + \gamma + \delta = 4$

36. (*a*) The fractional error in the measurement $\frac{\delta L}{L}$ is closest to 1%.

Given: Error in time $\delta T = 0.01$s, length is 20 m and acceleration due to gravity is 10 m/s².

The time expression in terms of L and g is;

$T = \sqrt{\frac{2L}{g}} + \frac{L}{V}$

And the error is given as;

$\Delta T = \Delta A + \Delta B$

$\Delta T = \sqrt{\frac{2}{g}} \times \frac{\Delta L}{2\sqrt{L}} + \frac{\Delta L}{V}$

$\Delta T = \sqrt{\frac{1}{2gL}} \times \Delta L + \frac{\Delta L}{V}$

$0.01 = \frac{1}{\sqrt{2 \times 10 \times 20}} \times \Delta L + \frac{\Delta L}{300}$.

$0.01 = \Delta L\left[\frac{1}{20} + \frac{1}{300}\right]$

On calculating we get,

$\Delta L = 0.1875$

$\frac{\Delta L}{L} \times 100 = \frac{0.1875}{20} \times 100 = 1\%$

37. (*a*) The given relation of diode is given as:

$I = \left(e^{1000\frac{V}{T}} - 1\right)$ mA

Putting $I = 5$ A;

$5 = e^{1000\frac{V}{T}} - 1$

$\Rightarrow e^{1000\frac{V}{T}} = 6$ ...(*i*)

Again, $I = e^{1000\frac{V}{T}} - 1$

Differentiating w.r.t. V:

$\frac{dI}{dV} = e^{\frac{1000V}{T}} \frac{1000}{T}$

$dI = \frac{1000}{T} e^{\frac{1000}{T}V} dV$

Using (*i*)

$\Delta I = \frac{1000}{T} \times 6 \times 0.01 = \frac{60}{300} = 0.2$ mA

38. (*a*) Due to the errors in the measurements of d and l are the same.

Least count is given as;

$L.C. = \frac{0.5}{100} = 0.005$

$\frac{\Delta Y}{Y} = \frac{\Delta l}{l} + \frac{2\Delta d}{d}$

Error for l;

$\frac{\Delta l}{l} = \frac{0.005 \times 10^{-3}}{0.25 \times 10^{-3}} = \frac{1}{50}$

Error for d;

$\frac{2\Delta d}{d} = \frac{2 \times 0.005 \times 10^{-3}}{0.5 \times 10^{-3}} = \frac{1}{50}$

39. (*c*) **Given:** Screw gauge readings, Pitch = 0.5 mm, Circular scale division = 50.

Main scale reading = 2.5 mm

Least count $= \frac{0.5}{50} = 0.01$ mm and

Circular scale division reading = 20 divisions

We have, Relative error = 2%

Then dimensions reading from screw gauge = Diameter of a solid ball

S.G. Reading = main scale reading $+\left(\frac{\text{pitch}}{\text{circular scale division}}\right) \times$ circular scale division reading

Diameter of solid ball

$= 2.5 + \frac{0.5}{50} \times 20 = 2.7$ mm

As density $\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{\frac{4\pi}{3}\left(\frac{D}{2}\right)^3}$

The relative percentage error in the density is

$\frac{\Delta\rho}{\rho} \times 100 = \left(\frac{\Delta M}{M} + \frac{3\Delta D}{D}\right) \times 100$

$\%$ error $= \left(\frac{\Delta M}{M} + \frac{3\Delta D}{D}\right) \times 100$

$= \left(2 + 3 \times \frac{0.01}{2.7}\right) \times 100 = 3.1\%$

40. (*a,c*) Relative error in measurement of time,

$= \frac{\Delta t}{t} = \frac{1\text{s}}{40\text{s}} = \frac{1}{40}$

Time period, $T = \frac{40\text{s}}{20} = 2\text{s}$

Error in measurement of time period,

$\Delta T = T \times \frac{\Delta t}{t} = 2\text{s} \times \frac{1}{40} = 0.05\text{s}$

The time period of simple pendulum is

$T = 2\pi\sqrt{\frac{l}{g}}$ or $T^2 = \frac{4\pi^2 l}{g}$ or $g = \frac{4\pi^2 l}{T^2}$

$\therefore \frac{\Delta g}{g} = \frac{2\Delta T}{T} = 2 \times \frac{1}{40} = \frac{1}{20}\left(\because \frac{\Delta T}{T} = \frac{\Delta t}{t}\right.$

Percentage error in determination of g is

$\frac{\Delta g}{g} \times 100 = \frac{1}{20} \times 100 = 5\%$

41. (*b*) Using Young's modulus expression:

$Y = \frac{4Fl}{\pi D^2 e}$

Taking log on both the sides log

$Y = \log 4\ Fl - \log \pi D^2 e$

Now, partially differentiating,

@FAKE_OBJECT@RAJ_EDUNET

$$\frac{\Delta Y}{Y} = -\left(\frac{2\Delta D}{D} + \frac{\Delta e}{e}\right)$$

$$\Rightarrow \frac{\Delta Y}{Y} = -\left(\frac{2\times 0.01}{0.4} + \frac{0.05}{0.8}\right) \Rightarrow \frac{\Delta Y}{Y}$$

$$= -0.1125$$

Also, $Y = \frac{F}{Ae} = \frac{9.8\times 2}{\pi(0.2)^2 \times 0.8}$

$$= 194.96 \times 10^9 \approx 2 \times 10^{11}$$

$$\Delta Y = -Y \times \left(\frac{2\Delta r}{r} + \frac{\Delta e}{e}\right)$$

$$\Delta Y = 0.225 \times 10^{11}$$

$$Y = (2 \pm 0.2) \times 10^{11}\ \text{Nm}^{-2}$$

42. (*d*) The diameter of the sphere is 2.25 mm.
Given: Pitch of the circular scale $P = 0.5$ mm.
Number of divisions on circular scale $N = 50$.
Least count of screw gauge is given as:

$$L.C. = \frac{P}{N} = \frac{0.5}{50}\ \text{mm} = 0.01\ \text{mm}$$

Now, main scale reading is M.S.R. = 2 mm marking on circular scale $n = 25$.
Thus, diameter of sphere
$d = \text{M.S.R.} + n \times \text{L.C.}$
$\Rightarrow d = 2\ \text{mm} + 25 \times 0.01\ \text{mm} = 2.25\ \text{mm}$

43. (*d*) The maximum percentage error in the measurement of its density is 4%.
The volume of the wire is given by, $V = \pi r^2 L$

Thus density of the wire, $\rho = \frac{m}{\pi r^2 L}$

Taking log and then differentiate:

$$\Rightarrow \frac{\Delta\rho}{\rho}\times 100 = \frac{\Delta m}{m}\times 100 + 2\frac{\Delta r}{r} \times 100 + \frac{\Delta L}{L}\times 100$$

$$\therefore \frac{\Delta\rho}{\rho}\times 100 = \frac{0.003}{0.3}\times 100 + 2\frac{0.005}{0.5}\times 100 + \frac{0.06}{6}\times 100$$

$$= 4\%\ \text{(error)}$$

Percentage error in density is 4%.

44. (*b*) Given:

$$r = \frac{1-a}{1+a}$$

Now, on differentiating;

$$dr = -\frac{da}{1+a} + \frac{(1-a)(-1)}{(1+a)^2}da$$

$$= \frac{+da}{1+a} + \frac{da(1-a)}{(1+a)^2}$$

(negative errors are also added)

$$= \frac{da}{1+a}\left[1 + \frac{1-a}{1+a}\right]$$

$$= \frac{da}{1+a}\left[\frac{1+a+1-a}{1+a}\right]$$

Error in Δr:

$$dr = \frac{2da}{(1+a)^2} = \frac{2\Delta a}{(1+a)^2}$$

45. (*c*) The error $\Delta\lambda$, in the determination of the decay constant λ in s^{-1}, is 0.02.
We know that,
$N = N_0 e^{-\lambda t} \Rightarrow \ln N = \ln N_0 - \lambda t$,

$$\frac{\Delta N}{N} = \Delta\lambda t \Rightarrow \Delta\lambda = \frac{\Delta N}{Nt}$$

Now we differentiating above eq" w.r.t then we get,
Converting to error

$$\Rightarrow \frac{dN}{N} = -td$$

$$\frac{\Delta N}{N} = \Delta\lambda t \Rightarrow \Delta\lambda = \frac{\Delta N}{Nt}$$

$$\Delta\lambda = \frac{40}{2000\times 1} = 0.02$$

46. The percentage error in the value of $E(t)$ at $t = 5$s is 4%
Given function; $E(t) = A^2 e^{-\alpha t}$
Taking natural logarithm on both sides,
$\ln(E) = 2\ln(A) + (-\alpha t)$
Differentiating both sides

$$\frac{dE}{E} = \pm 2\frac{dA}{A} + (\alpha dt)$$

Errors always add up for maximum error.

$$\therefore \frac{dE}{E} = \pm\left(2\frac{dA}{A} + \alpha\left(\frac{dt}{t}\right)\times t\right)$$

Here,

$$\frac{dA}{A} = 1.25\%, \frac{dt}{t}$$

$= 1.5\%, t = 5\text{s}, a = 0.2\text{s}^{-1}$

$$\therefore \frac{dE}{E} = \pm[(2\times 1.25\%) + (0.2) \times (1.5\%) \times 5] = \pm 4\%$$

47. (*c*) Given $10\ VSD = 9\ MSD$

$$\text{Least count} = 1\ VSD = \frac{9}{10}\ MSD$$

$$\text{Least count} = 1\ MSD - 1\ VSD$$

$$= \left(1 - \frac{9}{10}\right) MSD$$

$= 0.1\ MSD = 0.1 \times 0.1\ \text{cm} = 0.01\ \text{cm}$
As '0' of V.S. lie before '0' of M.S.

Zero error $= -[10 - 6]$ L.C.
$= -4 \times 0.01$ cm
$= -0.04$ cm
Reading $= 3.1\ \text{cm} + 1 \times \text{LC}$
$= 3.4\ \text{cm} + 1 \times 0.01\ \text{cm}$
$= 3.11\ \text{cm}$
True diameter = Reading − Zero error
$= 3.11 - (-0.04)\ \text{cm} = 3.15\ \text{cm}$

48. (*b*) Given:
$d = 0.5$ mm, $Y = 2 \times 10^{11}$, $l = 1$ m, $m = 1.2$ Kg
Using formula, putting all the values:

$$\Delta l = \frac{Fl}{Ay} = \frac{mgl}{\frac{\pi d^2}{4}y}$$

$$= \frac{\pi}{\frac{\pi}{4}\times(5\times 10^{-4})^2 \times 2\times 10^{11}}$$

$$\Delta l = \frac{1.2\times 10\times 1}{\frac{3.2}{4}\times 25\times 10^{-8}\times 2\times 10^{11}}$$

$$= \frac{12}{0.8\times 25\times 2\times 10^3} = \frac{12}{40\times 10^3} = 0.3\ \text{mm}$$

So 3rd division of vernier scale will coincide with main scale.
Also, $\angle C$ of vernier scale

$$= \left(1 - \frac{ms}{vs}\right) ms\angle C$$

$$= \left(1 - \frac{9}{10}\right)\times 1mm = 0.1\ \text{mm}$$

49. (*b*) 2.87 and 2.83 is the correct answer.
Given:

$$MSD = \frac{1}{10}\ \text{cm} = 0.1\ \text{cm}$$

For first vernier caliper, $10\ VSD = 9\ MSD$

$$\Rightarrow VSD = \frac{9}{10} MSD = 0.9 \times 0.1$$

$$= 0.09\ \text{cm}$$

Reading = main scale reading up to coinciding main scale division $- n \times VSD$
$= 3.5 - 7 \times 0.09 = 3.5 - 0.63 = 2.87$ cm
For second vernier caliper,
$10\ VSD = 11\ MSD$

$$\Rightarrow VSD = \frac{11}{10} MSD = 1.1 \times 0.1 = 0.11\text{cm}$$

Reading $= 3.6 - 7 \times 0.11 = 3.6 - 0.7$
$= 2.83$ cm

50. (*b*) The diameter of the cylinder is 5.124 c
Main scale division(s) = 0.05 cm
Also, vernier scale division

$$(v) = \frac{2.45}{50} = \frac{4.9}{100} = 0.049\ \text{cm/div}$$

@TAKE CBSE KORALEDUNET

Thus, least count = 0.05 − 0.049
= 0.001 cm
Hence, Diameter of the cylinder
= 5.10 + 24 × 0.001 = 5.124 cm

51. (*d*) **Step 1:** Vernier Scale divisions
Given, 20 divisions of Vernier scale = 16 divisions of main scale 1 division
of Vernier scale $= \frac{16}{20}$ divisions of main scale.
So, 1 V.S.D $= \frac{16}{20} \times 1\,\text{mm} = 0.8\,\text{mm}$

Step 2: Least count
Least count = 1 M.S.D. − 1 V.S.D.
where, M.S.D. = main scale divisions
V.S.D. = Vernier scale divisions
Least Count = 1 mm − 0.8 mm
= 0.2 mm

52. (*d*) Taking the time expression;

$$T = 2\pi\sqrt{\frac{T}{g}} \Rightarrow g = \frac{4\pi^2 l}{T^2}$$

$$\Rightarrow \frac{\Delta g}{g} = \frac{\Delta l}{l} + \frac{2\Delta T}{T}$$

For Student I,

$$E_I = \left(\frac{0.1}{64.0} + \frac{2\times 0.1}{128.0}\right)\times 100 = 0.3125\%$$

For Student II,

$$E_{II} = \left(\frac{0.1}{64.0} + \frac{2\times 0.1}{64.0}\right)\times 100 = 0.4688\%$$

For Student III,

$$E_{III} = \left(\frac{0.1}{20.0} + \frac{2\times 0.1}{36.0}\right)\times 100 = 1.056\%$$

Therefore, percentage error is maximum for Student III.

53. (*b, c*) **Vernier Calipers:** 1 cm is divided into 8 divisions, 1 main scale division is given as $\frac{1}{8}$cm. L.C. of Vernier is given as
1M.S.D - 1V.S.D
Given: 5 Vernier scale coincides with 4 main scale divisions:
5V.S.D = 4M.S.D.

$$\text{L.C.} = 1\text{M.S.D.} - \frac{4}{5}\text{M.S.D.}$$

$$\text{L.C.} = 1\text{M.S.D.} - \frac{4}{5}\text{M.S.D.} = \frac{1}{5}\text{M.S.D.}$$

$$= \frac{1}{40}\text{ cm}$$

Checking option (*a*) and (*b*):
Given pitch of Screw gauge is 2 times L.C. of V.S.

$$p = 2\times\frac{1}{40}\text{cm} = \frac{1}{20}\text{cm}$$

$$\text{The least count of screw gauge is } \frac{\text{pitch}}{\text{No. of divisions on circular scale}}$$

No. of divisions on circular scale = 100

$$= \frac{\frac{1}{20}}{100} = 0.0005\,\text{cm} = 0.005\,\text{mm}$$

Given least count of the linear scale of the screw gauge is twice the least count of the Vernier calipers. One complete rotation of the circular scale moves it by two divisions on the linear scale, so pitch is 2 times linear scale division of screw gauge,
Pitch = 2 × linear scale division of screw gauge
= 2 × 2 × L.C. of V.S. = 4 × L.C. of V.S.

$$= 4\times\frac{1}{40} = \frac{1}{10}$$

The least count of screw gauge is no. of divisions on circular scale
No. of divisions on circular scale = 100

$$\text{L.C.} = \frac{\frac{1}{10}}{100} = 0.001\,\text{cm} = 0.01\,\text{mm}$$

54. [4] The maximum percentage error in the Young's modulus of the wire is

$$\therefore \frac{\Delta Y}{Y}\times 100 = \frac{(LC)}{25(LC)}\times 100 = 4\%$$

$Y = \frac{FL}{lA}$ since the experiment measures only change in the length of wire

$$\therefore \frac{\Delta Y}{Y}\times 100 = \frac{\Delta l}{l}\times 100$$

From the observation:
$l_1 = MSR + 20(LC)$ (MSR – Main Scale Reading)
$l_2 = MSR + 45(LC)$
$\Rightarrow$ change in lengths $= 25(LC)$

$$\therefore \frac{\Delta Y}{Y}\times 100 = \frac{(LC)}{25(LC)}\times 100 = 4\%$$

55. [2.66] The density in g/cm³ upto correct significant figures is:
Density of the cube

$$= \frac{2.736}{1.030301} = 2.66\,\text{gm/cm}^3$$

We have, 1 MSD = 1 mm
L.C. = 1 MSD − 1VSD

$$= 1\,\text{mm} - \frac{9}{10}\,\text{mm} = \frac{1}{10}\,\text{mm}$$

Measured reading of edge
= MSR + VSR × (LC)

$$= 10 + 1\times\frac{1}{10} = 10.1\,\text{mm}$$

Volume of cube = $(10.1)^3$ = 1030.301 mm³
= 1.030301 cm³
Density of the cube

$$= \frac{2.736}{1.030301} = 2.66\,\text{gm/cm}^3$$

56. [2.6] The curved surface area (in cm²) of the wire is 2.586 ≈ 2.6 cm²
Given: Main scale reading = 1 mm
Circular scale reading = 0.01 × 47 = 0.47
Diameter of wire = Total reading
= 1.47 mm = 0.147 cm
Curved surface area = $\pi \times dl = \pi \times (0.147)(5.6) = 2.586 \approx 2.6\ \text{cm}^2$

57. $(n+1)\,VSD = nMSD$

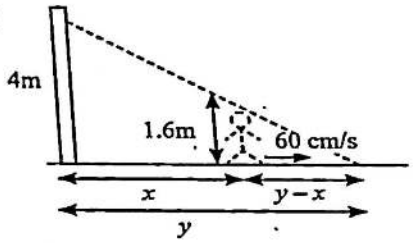
$$1VSD = \frac{n}{n+1}MSD$$

Least count of vernier calipers:

$$= 1MDS - 1VSD$$

$$= \left[1 - \frac{n}{n+1}\right]MSD = \left[\frac{a}{n+1}\right]\text{unit.}$$

58. [40]



From the property of similar triangle,

$$\frac{4}{y} = \frac{1.6}{y-x} \Rightarrow x = 0.6y$$

$$\frac{dx}{dt} = 0.6\times\frac{dy}{dt} \Rightarrow 60 = 0.6\times\frac{dy}{dt}$$

$$\therefore \frac{dy}{dt} = 100\text{ cm/s}$$

Speed of tip of person's. Shadow w.r. person = 100 − 60 = 40 cm/s

@TAKE_CBSE_X@RAJ_EDUVET

2 Vector and Calculus

Scan for Sol.

JEE-Main

Addition and Subtraction of Two Vectors

1. If two vectors $\vec{A}$ and $\vec{B}$ having equal magnitude R are inclined at an angle θ, then **[31 Jan, 2024 (Shift-II)]**

(a) $|\vec{A}-\vec{B}|=\sqrt{2}R\sin\frac{\theta}{2}$ (b) $|\vec{A}+\vec{B}|=2R\sin\frac{\theta}{2}$

(c) $|\vec{A}+\vec{B}|=2R\cos\frac{\theta}{2}$ (d) $|\vec{A}-\vec{B}|=2R\cos\frac{\theta}{2}$

2. A vector has magnitude same as that of $\vec{A}=3\hat{i}+4\hat{j}$ and is parallel to $\vec{B}=4\hat{i}+3\hat{j}$. The x and y components of this vector in first quadrant are x and 3 respectively where $x=$ _____. **[30 Jan, 2024 (Shift-II)]**

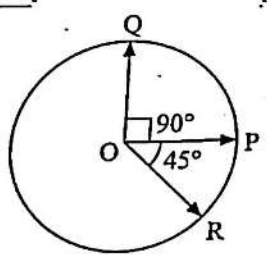
3. Two forces $\vec{F}_1$ and $\vec{F}_2$ are acting on a body. One force has magnitude thrice that of the other force and the resultant of the two forces is equal to the force of larger magnitude. The angle between $\vec{F}_1$ and $\vec{F}_2$ is $\cos^{-1}\left(\frac{1}{n}\right)$. The value of $|n|$ is ____. **[04 April, 2024 (Shift-I)]**

4. The angle between vector $\vec{Q}$ and the resultant of $(2\vec{Q}+2\vec{P})$ and $(2\vec{Q}-2\vec{P})$ is: **[05 April, 2024 (Shift-I)]**

(a) $0°$ (b) $\tan^{-1}\frac{(2\vec{Q}-2\vec{P})}{2\vec{Q}+2\vec{P}}$

(c) $\tan^{-1}\left(\frac{P}{Q}\right)$ (d) $\tan^{-1}\left(\frac{2Q}{P}\right)$

5. Three vectors $\overline{OP}$, $\overline{OQ}$ and $\overline{OR}$ each of magnitude A are acting as shown in figure. The resultant of the three vectors is $A\sqrt{x}$. The value of x is _____. **[08 April, 2024 (Shift-I)]**



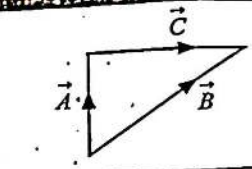
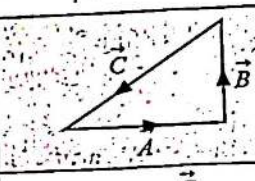
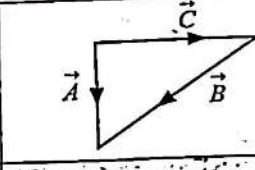
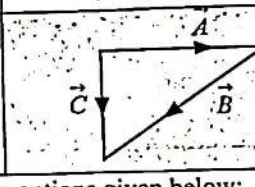
6. If $\vec{a}$ and $\vec{b}$ makes an angle $\cos^{-1}\left(\frac{5}{9}\right)$ with each other, then $|\vec{a}+\vec{b}|=\sqrt{2}|\vec{a}-\vec{b}|$ for $|\vec{a}|=n|\vec{b}|$. The integer value of n is _____. **[09 April, 2024 (Shift-I)]**

7. The resultant of two vectors $\vec{A}$ and $\vec{B}$ is perpendicular to $\vec{A}$ and its magnitude is half that of $\vec{B}$. The angle between vectors $\vec{A}$ and $\vec{B}$ is ..... **[09 April, 2024 (Shift-II)]**

8. When vector $\vec{A}=2\hat{i}+3\hat{j}+2\hat{k}$ is subtracted from vector $\vec{B}$, it gives a vector equal to $2\hat{j}$. Then the magnitude of vector $\vec{B}$ will be: **[11 April, 2023 (Shift-II)]**

(a) $\sqrt{13}$ (b) 3 (c) $\sqrt{6}$ (d) $\sqrt{5}$

9. Match List-I with List-II.

List-I		List-II	
A.	$\vec{C}-\vec{A}-\vec{B}=0$	I.	
B.	$\vec{A}-\vec{C}-\vec{B}=0$	II.	
C.	$\vec{B}-\vec{A}-\vec{C}=0$	III.	
D.	$\vec{A}+\vec{B}=-\vec{C}$	IV.	

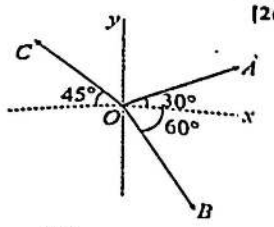
Choose the correct answer from the options given below: **[25 July, 2021 (Shift-I)]**

(a) A-IV, B-I, C-III, D-II (b) A-IV, B-III, C-I, D-II

(c) A-I, B-IV, C-II, D-III (d) A-III, B-II, C-IV, D-I

@FAKE_CBSE_QA_LEDUNET

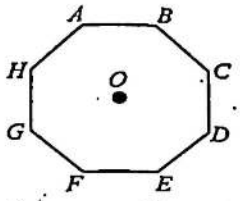
10. The magnitude of vectors $\overrightarrow{OA}$, $\overrightarrow{OB}$ and $\overrightarrow{OC}$ in the given figure are equal. The direction of $\overrightarrow{OA}+\overrightarrow{OB}-\overrightarrow{OC}$ with x-axis will be **[26 Aug, 2021 (Shift-I)]**



(a) $\tan^{-1}\frac{(\sqrt{3}-1+\sqrt{2})}{(1-\sqrt{3}+\sqrt{2})}$ (b) $\tan^{-1}\frac{(1+\sqrt{3}-\sqrt{2})}{(1-\sqrt{3}-\sqrt{2})}$

(c) $\tan^{-1}\frac{(1-\sqrt{3}-\sqrt{2})}{(1+\sqrt{3}+\sqrt{2})}$ (d) $\tan^{-1}\frac{(\sqrt{3}-1+\sqrt{2})}{(1+\sqrt{3}-\sqrt{2})}$

11. In an octagon $ABCDEFGH$ of equal side, what is the sum of $\overrightarrow{AB}+\overrightarrow{AC}+\overrightarrow{AD}+\overrightarrow{AE}+\overrightarrow{AF}+\overrightarrow{AG}+\overrightarrow{AH}$, if, $\overrightarrow{AO}=2\hat{i}+3\hat{j}-4\hat{k}$ **[25 Feb, 2021 (Shift-I)]**

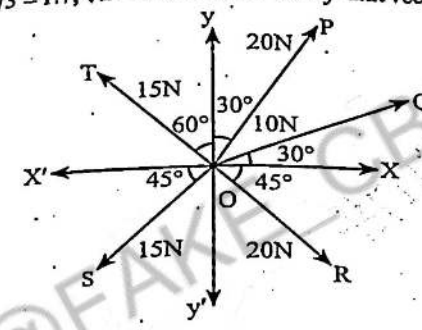


(a) $16\hat{i}+24\hat{j}-32\hat{k}$ (b) $16\hat{i}-24\hat{j}+32\hat{k}$

(c) $-16\hat{i}-24\hat{j}+32\hat{k}$ (d) $16\hat{i}+24\hat{j}-32\hat{k}$

12. The resultant of these forces $\overrightarrow{OP},\overrightarrow{OQ},\overrightarrow{OR},\overrightarrow{OS}$ and $\overrightarrow{OT}$ is approximately ..... N. **[27 Aug, 2021 (Shift-I)]**

[Take $\sqrt{3}=1.7,\sqrt{2}=1.4$ .Given $\hat{i}$ and $\hat{j}$ unit vectors along x,y axis]



(a) $9.25\hat{i}+5\hat{j}$ (b) $2.5\hat{i}-14.5\hat{j}$

(c) $-1.5\hat{i}-15.5\hat{j}$ (d) $3\hat{i}+15\hat{j}$

13. **Statement-I:** If three forces $\vec{F}_1,\vec{F}_2$ and $\vec{F}_3$ are represented by three sides of a triangle and, $\vec{F}_1+\vec{F}_2=-\vec{F}_3$ then these three forces are concurrent forces and satisfy the condition for equilibrium. **[31 Aug, 2021 (Shift-II)]**

Statement-II: A triangle made up of three forces $\vec{F}_1,\vec{F}_2$ and $\vec{F}_3$ as its sides taken in the same order, satisfy the condition for translatory equilibrium. In the light of the above statements, choose the most appropriate answer from the options given below:

(a) Statement-I is false but Statement-II is true

(b) Both Statement-I and Statement-II are true

(c) Statement-I is true but Statement-II is false

(d) Both Statement-I and Statement-II are false

14. Two forces having magnitude A and $\frac{A}{2}$ are perpendicular to each other. The magnitude of their resultant is **[8 April, 2023 (Shift-I)]**

(a) $\frac{\sqrt{5}A}{4}$ (b) $\frac{5A}{2}$ (c) $\frac{\sqrt{5}A^2}{2}$ (d) $\frac{\sqrt{5}A}{2}$

15. A vector in x–y plane makes an angle of 30° with y-axis. The magnitude of y-component of vector is $2\sqrt{3}$. The magnitude of x-component of the vector will be: **[15 April, 2023 (Shift-I)]**

(a) $\frac{1}{\sqrt{3}}$ (b) 6 (c) $\sqrt{3}$ (d) 2

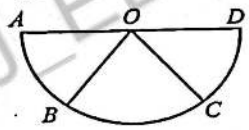
16. A mosquito is moving with a velocity $\vec{v}=0.5t^2\hat{i}+3\hat{j}+9\hat{k}$ m/s and accelerating in uniform conditions What will be the direction of mosquito after 2s? **[16 March, 2021 (Shift-II)]**

(a) $\tan^{-1}\left(\frac{\sqrt{85}}{6}\right)$ from y-axis (b) $\tan^{-1}\left(\frac{5}{2}\right)$ from y-axis

(c) $\tan^{-1}\left(\frac{2}{3}\right)$ from x-axis (d) $\tan^{-1}\left(\frac{5}{2}\right)$ from x-axis

17. **Assertion A:** If A, B, C and D are four points on a semicircular arc with centre at 'O' such that $|\overrightarrow{AB}|=|\overrightarrow{BC}|=|\overrightarrow{CD}|$, then $\overrightarrow{AB}+\overrightarrow{AC}+\overrightarrow{AD}=4\overrightarrow{AO}+\overrightarrow{OB}+\overrightarrow{OC}$

Reason R: Polygon law of vector addition yields $\overrightarrow{AB}+\overrightarrow{BC}+\overrightarrow{CD}=\overrightarrow{AD}=2\overrightarrow{AO}$



In the light of the above statements, choose the most appropriate answer from the options given below: **[27 July, 2021 (Shift-I)]**

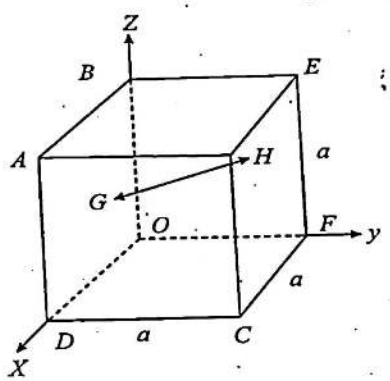
(a) **A** is not correct but **R** is correct.

(b) **A** is correct but **R** is not correct.

(c) Both **A** and **R** are correct and **R** is the correct explanation of **A**.

(d) Both **A** and **R** are correct but **R** is not the correct explanation of **A**.

18. In the cube of side 'a' shown in the figure, the vector from the central point of the face $ABOD$ to the central point of the face $BEFO$ will be **[10 Jan, 2019 (Shift-I)]**



(a) $\frac{1}{2}a(\hat{k}-\hat{i})$ (b) $\frac{1}{2}a(\hat{i}-\hat{k})$

(c) $\frac{1}{2}a(\hat{j}-\hat{i})$ (d) $\frac{1}{2}a(\hat{j}-\hat{k})$

@FAKE_CBSE_X @RAJ_EDUNET

Dot Product

19. If two vectors $\vec{P}=\hat{i}+2m\hat{j}+m\hat{k}$ and $\vec{Q}=4\hat{i}-2\hat{j}+m\hat{k}$ are perpendicular to each other. Then, the value of m will be:
[24 Jan, 2023 (Shift-II)]

(a) 1 (b) −1 (c) −3 (d) 2

20. Vectors $a\hat{i}+b\hat{j}+\hat{k}$ and $2\hat{i}-3\hat{j}+4\hat{k}$ are perpendicular to each other when $3a + 2b = 7$, the ratio of a to b is $\frac{x}{2}$. The value of x is _____.
[24 Jan, 2023 (Shift-I)]

21. Which of the following relations is true for two unit vector $\hat{A}$ and $\hat{B}$ making an angle θ to each other?
[25 June, 2022 (Shift-I)]

(a) $|\hat{A}+\hat{B}|=|\hat{A}-\hat{B}|\tan\frac{\theta}{2}$ (b) $|\hat{A}-\hat{B}|=|\hat{A}+\hat{B}|\tan\frac{\theta}{2}$

(c) $|\hat{A}+\hat{B}|=|\hat{A}-\hat{B}|\cos\frac{\theta}{2}$ (d) $|\hat{A}-\hat{B}|=|\hat{A}+\hat{B}|\cos\frac{\theta}{2}$

22. Two vectors $\vec{A}$ and $\vec{B}$ have equal magnitudes. If magnitude of $\vec{A}+\vec{B}$ is equal to two times the magnitude of $\vec{A}-\vec{B}$, then the angle between $\vec{A}$ and $\vec{B}$ will be:
[29 June, 2022 (Shift-I)]

(a) $\sin^{-1}\left(\frac{3}{5}\right)$ (b) $\sin^{-1}\left(\frac{1}{3}\right)$

(c) $\cos^{-1}\left(\frac{3}{5}\right)$ (d) $\cos^{-1}\left(\frac{1}{3}\right)$

23. If $\vec{A}=(2\hat{i}+3\hat{j}-\hat{k})m$ and $\vec{B}=(\hat{i}+2\hat{j}-2\hat{k})m$. The magnitude of component of vector $\vec{A}$ along vector $\vec{B}$ will be _____ m.
[26 July, 2022 (Shift-II)]

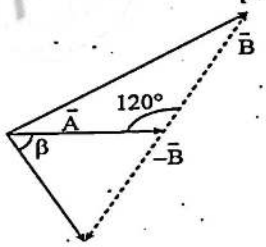
24. If the projection of $2\hat{i}+4\hat{j}-2\hat{k}$ on $\hat{i}+2\hat{j}+\alpha\hat{k}$ is zero. Then, the value of α will be _____.
[28 July, 2022 (Shift-I)]

25. If $\vec{A}$ and $\vec{B}$ are two vectors satisfying the relation $\vec{A}.\vec{B}=|\vec{A}\times\vec{B}|$. Then the value of $|\vec{A}-\vec{B}|$ will be:
[20 July, 2021 (Shift-I)]

(a) $\sqrt{A^2+B^2-\sqrt{2}AB}$ (b) $\sqrt{A^2+B^2}$

(c) $\sqrt{A^2+B^2+2AB}$ (d) $\sqrt{A^2+B^2+\sqrt{2}AB}$

26. The angle between vector $(\vec{A})$ and $(\vec{A}-\vec{B})$ is:
[26 Aug, 2021 (Shift-II)]



(a) $\tan^{-1}\left(\frac{\sqrt{3}B}{2A-B}\right)$ (b) $\tan^{-1}\left(\frac{B\cos\theta}{A-B\sin\theta}\right)$

(c) $\tan^{-1}\left(\frac{A}{0.7B}\right)$ (d) $\tan^{-1}\left(\frac{\frac{-B}{2}}{A-B\frac{\sqrt{3}}{2}}\right)$

27. What will be the projection of vector $\vec{A}=\hat{i}+\hat{j}+\hat{k}$ on vector $\vec{B}=\hat{i}+\hat{j}$?
[22 July, 2021 (Shift-II)]

(a) $2(\hat{i}+\hat{j}+\hat{k})$ (b) $\sqrt{2}(\hat{i}+\hat{j})$

(c) $(\hat{i}+\hat{j})$ (d) $\sqrt{2}(\hat{i}+\hat{j}+\hat{k})$

28. Two vectors $\vec{A}$ and $\vec{B}$ have equal magnitudes. The magnitude of $(\vec{A}+\vec{B})$ is 'n' times the magnitude of $(\vec{A}-\vec{B})$. The angle between $\vec{A}$ and $\vec{B}$ is:

(a) $\cos^{-1}\left[\frac{n^2-1}{n^2+1}\right]$ (b) $\cos^{-1}\left[\frac{n-1}{n+1}\right]$

(c) $\sin^{-1}\left[\frac{n^2-1}{n^2+1}\right]$ (d) $\sin^{-1}\left[\frac{n-1}{n+1}\right]$

29. Two vectors $\vec{X}$ and $\vec{Y}$ have equal magnitude. The magnitude of $(\vec{X}-\vec{Y})$ is n times the magnitude of $(\vec{X}+\vec{Y})$. The angle between $\vec{X}$ and $\vec{Y}$ is:
[25 July, 2021 (Shift-II)]

(a) $\cos^{-1}\left(\frac{n^2+1}{n^2-1}\right)$ (b) $\cos^{-1}\left(\frac{-n^2-1}{n^2-1}\right)$

(c) $\cos^{-1}\left(\frac{n^2-1}{-n^2-1}\right)$ (d) $\cos^{-1}\left(\frac{n^2+1}{-n^2-1}\right)$

30. **Statement-I:** Two forces $(\vec{P}+\vec{Q})$ and $(\vec{P}-\vec{Q})$ where $\vec{P}\perp\vec{Q}$, when act at an angle θ_1 to each other, the magnitude of their resultant is $\sqrt{3(P^2+Q^2)}$, when they act at an angle θ_2, the magnitude of their resultant becomes $\sqrt{2(P^2+Q^2)}$. This is possible only when $\theta_1<\theta_2$.
[31 Aug, 2021 (Shift-II)]

Statement-II: In the situation given above. $\theta_1=60°$ and $\theta_2=90°$.

In the light of the above statements, choose the most appropriate answer from the options given below:

(a) Both Statement-I and Statement-II are true

(b) Both Statement-I and Statement-II are false

(c) Statement-I is true but Statement-II is false

(d) Statement-I is false but Statement-II is true

31. The sum of two forces $\vec{P}$ and $\vec{Q}$ is $\vec{R}$ such that $|\vec{R}|=|\vec{P}|$. The angle θ (in degrees) that the resultant of $2\vec{P}$ and $\vec{Q}$ will make with $\vec{Q}$ is
[7 Jan, 2020 (Shift-I)]

32. Let $|\vec{A}_1|=3, |\vec{A}_2|=5$ and $|\vec{A}_1+\vec{A}_2|=5$. The value of $(2\vec{A}_1+3\vec{A}_2).(3\vec{A}_1-2\vec{A}_2)$ is:
[8 April, 2019 (Shift-II)]

(a) −112.5 (b) −106.5

(c) −118.5 (d) −99.5

33. Two forces P and Q, of magnitude $2F$ and $3F$, respectively, are at an angle θ with each other. If the force Q is doubled, then the resultant also gets doubled. Then, the angle θ is:
[10 Jan, 2019 (Shift-II)]

(a) 120° (b) 60° (c) 90° (d) 30°

@FAKE_CODER @TELEDUNET

Cross Product

34. For three vectors $\vec{A}=(-x\hat{i}-6\hat{j}-2\hat{k})$, $\vec{B}=(-\hat{i}+4\hat{j}+3\hat{k})$ and $\vec{C}=(-8\hat{i}+\hat{j}+3\hat{k})$, if $\vec{A}\cdot(\vec{B}\times\vec{C})=0$, then value of x is _____.
[06 April, 2024 (Shift-I)]

35. If $\vec{P}=3\hat{i}+\sqrt{3}\hat{j}+2\hat{k}$ and $\vec{Q}=4\hat{i}+\sqrt{3}\hat{j}+2.5\hat{k}$ then, the unit vector in the direction of $\vec{P}\times\vec{Q}$ is $\frac{1}{x}\left(\sqrt{3}\hat{i}+\hat{j}-2\sqrt{3}\hat{k}\right)$. The value of x is
[25 Jan, 2023 (Shift-I)]

36. $\vec{A}$ is a vector quantity such that $|\vec{A}|=$ non-zero constant. Which of the following expression is true for $\vec{A}$?
[25 June, 2022 (Shift-I)]

(a) $\vec{A}.\vec{A}=0$ (b) $\vec{A}\times\vec{A}<0$
(c) $\vec{A}\times\vec{A}=0$ (d) $\vec{A}\times\vec{A}>0$

37. If force $\vec{F}=3\hat{i}+4\hat{j}-2\hat{k}$ acts on a particle having position vector $2\hat{i}+\hat{j}+2\hat{k}$ then, the torque about the origin will be:
[25 June, 2022 (Shift-I)]

(a) $3\hat{i}+4\hat{j}-2\hat{k}$ (b) $-10\hat{i}+10\hat{j}+5\hat{k}$
(c) $10\hat{i}+5\hat{j}-10\hat{k}$ (b) $10\hat{i}+\hat{j}-5\hat{k}$

38. If $\vec{P}\times\vec{Q}=\vec{Q}\times\vec{P}$ the angle between $\vec{P}$ and $\vec{Q}$ is θ ($0°<\theta<360°$). The value of 'θ' will be _____
[25 Feb, 2021 (Shift-II)]

Function, Differentiation as a Rate Measurement

39. A person of height 1.6 m is walking away from a lamp post of height 4m along a straight path on the flat ground. The lamp post and the person are always perpendicular to the ground. If the speed of the person is 60 cm s^{-1}, the speed of the tip of the person's shadow on the ground with respect to the person is _____ cm s^{-1}.
[JEE Adv, 2023]

40. If $t=\sqrt{x}+4$, then $\left(\frac{dx}{dt}\right)_{t=4}$ is:
[29 July, 2022 (Shift-I)]

(a) 4 (b) zero
(c) 8 (d) 16

41. Three particles P, Q and R are moving along the vectors $\vec{A}=\hat{i}+\hat{j}, \vec{B}=\hat{j}+\hat{k}$ and $\vec{C}=-\hat{i}+\hat{j}$ respectively. They strike on point and start to move in different directions. Now particle P is moving normal to the plane which contains vector $\vec{A}$ and $\vec{B}$. Similarly particle Q is moving normal to the plane which contains vector $\vec{A}$ and $\vec{C}$. The angle between the direction of motion of P and Q is $\cos^{-1}\left(\frac{1}{\sqrt{x}}\right)$. Then the value of x is _____.
[22 July, 2021 (Shift-II)]

@FAKE_CBSE_X @RAJEDUNET

ANSWER KEY

JEE-Main

1. (c)	2. [4]	3. [6]	4. (a)	5. (c)	6. (c)	7. [150]	8. (*)	9. (b)	10. (c)
11. (a)	12. (a)	13. (b)	14. (d)	15. (d)	16. (a)	17. (d)	18. (c)	19. (d)	20. [1]
21. (b)	22. (c)	23. [2]	24. [5]	25. (a)	26. (a)	27. (c)	28. (a)	29. (c)	30. (a)
31. [90°]	32. (c)	33. (a)	34. [4]	35. [4]	36. (c)	37. (b)	38. [180]	39. [40]	40. (b)
41. [3]									

EXPLANATIONS

JEE-Main

1. (c) Resultant vector,

$\vec{R} = \sqrt{a^2 + b^2 + 2ab\cos\theta}$

According to question, $a = b = R$

$\vec{R} = \sqrt{R^2 + R^2 + 2R^2\cos\theta}$

$= R\sqrt{2}\sqrt{1+\cos\theta}$

$= \sqrt{2}R\sqrt{2\cos^2\frac{\theta}{2}} = 2R\cos\frac{\theta}{2}$

2. [4] $\vec{A} = 3\hat{i} + 4\hat{j}$ & $\vec{B} = 4\hat{i} + 3\hat{j}$

$\vec{N} = |\vec{A}|\hat{B} = \frac{5(4\hat{i}+3\hat{j})}{5} = 4\hat{i} + 3\hat{j}$

$\therefore \quad x = 4$

3. [6] $|\vec{F}_R| = |\vec{F}_3| = 3F$

$|\vec{F}_1| = F$

Now, $F_R^2 = F_1^2 + F_2^2 + 2F_1F_2\cos\theta$

$\Rightarrow 9F^2 = F^2 + 9F^2 + 6F^2\cos\theta$

$\Rightarrow \cos\theta = -\frac{1}{6} \Rightarrow \theta = \cos^{-1}\left(\frac{1}{-6}\right)$

$\therefore n = -6$ and $|n| = 6$

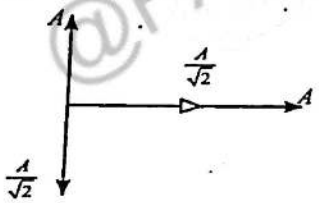
4. (a) Let the resultant of both the vectors be $\vec{R}$, then

$\vec{R} = (2\vec{Q} + 2\vec{P}) + (2\vec{Q} - 2\vec{P})$

$\vec{R} = 4\vec{Q}$

Angle between $\vec{Q}$ and $\vec{R}$ is zero.

5. (c) Resolving $\overrightarrow{OR}$



the resultant of the three vectors,

$\vec{R} = \left(A + \frac{A}{\sqrt{2}}\right)\hat{i} + \left(A - \frac{A}{\sqrt{2}}\right)\hat{j}$

the resultant of the three vectors,

$|\vec{R}| = \sqrt{\left(A + \frac{A}{\sqrt{2}}\right)^2 + \left(A - \frac{A}{\sqrt{2}}\right)^2} = \sqrt{3}A$

6. (c) Given: $\cos\theta = \frac{5}{9}$

$\Rightarrow \frac{\vec{a}\cdot\vec{b}}{ab} = \frac{5}{9}$ ...(i)

$\Rightarrow |\vec{a} + \vec{b}| = \sqrt{2}|\vec{a} - \vec{b}|$

$\Rightarrow a^2 + b^2 + 2\vec{a}\cdot\vec{b} = 2a^2 + 2b^2 - 4\vec{a}\cdot\vec{b}$

$\Rightarrow 6\vec{a}\cdot\vec{b} = a^2 + b^2$

$\Rightarrow 6 \times \frac{5}{9}ab = a^2 + b^2$

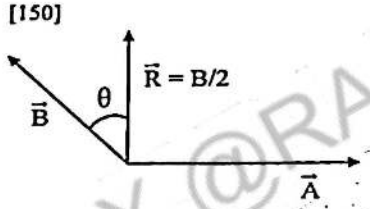
$\Rightarrow \frac{10}{3}ab = a^2 + b^2$ & $a = nb$

$\Rightarrow 3n^2 - 10n + 3 = 0$

$\Rightarrow n = \frac{1}{3}$ and $n = 3$

Thus, $n = 3$

7. [150]



According to the question.

$B\cos\theta = \frac{B}{2} \Rightarrow \theta = 60°$

Hence, the angle between $\vec{A}$ & $\vec{B}$ is $90° + 60° = 150°$

8. (*) Given,

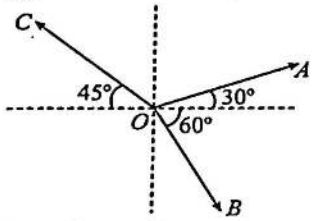
$\vec{B} - \vec{A} = 2\hat{j}, \vec{B} = 2\hat{j} + 2\hat{i} + 3\hat{j} + 2\hat{k}$

$\therefore \vec{B} = 2\hat{i} + 5\hat{j} + 2\hat{k}$

$|\vec{B}| = \sqrt{(2)^2 + (5)^2 + (2)^2} = \sqrt{33}$ (Bonus)

9. (b) Apply the triangle law of addition, to get answer.

10. (c)



According to diagram, let magnitude be equal to

$\overrightarrow{OA} = \lambda\left[\cos 30°\,\hat{i} + \sin 30\hat{j}\right] = \lambda\left[\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right]$

$\overrightarrow{OB} = \lambda\left[\cos 60°\,\hat{i} - \sin 60\hat{j}\right] = \lambda\left[\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j}\right]$

$\overrightarrow{OC} = \lambda\left[\cos 45°(-\hat{i}) + \sin 45\hat{j}\right] = \lambda\left[-\frac{1}{\sqrt{2}}\hat{i} + \frac{1}{\sqrt{2}}\hat{j}\right]$

$\therefore \overrightarrow{OA} + \overrightarrow{OB} - \overrightarrow{OC}$

$= \lambda\left[\left(\frac{\sqrt{3}+1}{2} + \frac{1}{\sqrt{2}}\right)\hat{i} + \left(\frac{1}{2} - \frac{\sqrt{3}}{2} - \frac{1}{\sqrt{2}}\right)\hat{j}\right]$

$\tan^{-1}\left[\frac{\frac{1}{2} - \frac{\sqrt{3}}{2} - \frac{1}{\sqrt{2}}}{\frac{\sqrt{3}}{2} + \frac{1}{2} + \frac{1}{\sqrt{2}}}\right] = \tan^{-1}\left[\frac{\sqrt{2} - \sqrt{6} - 2}{\sqrt{6} + \sqrt{2} + 2}\right]$

$= \tan^{-1}\left[\frac{1 - \sqrt{3} - \sqrt{2}}{\sqrt{3} + 1 + \sqrt{2}}\right]$

11. (a) $\overrightarrow{AB} + \overrightarrow{AH} = \overrightarrow{AO} \Rightarrow \overrightarrow{AC} + \overrightarrow{AG} = 2\overrightarrow{AO}$

$\overrightarrow{AD} + \overrightarrow{AF} = 3\overrightarrow{AO} \Rightarrow \overrightarrow{AE} = 2\overrightarrow{AO}$

Adding all,

$\overrightarrow{AB} + \overrightarrow{AC} + \overrightarrow{AD} + \overrightarrow{AE} + \overrightarrow{AF} + \overrightarrow{AG} + \overrightarrow{AH} = 8\overrightarrow{AO}$

$= 16\hat{i} + 24\hat{j} - 32\hat{k}$

$\overrightarrow{AB} + \overrightarrow{AO} + \overrightarrow{OB}, \overrightarrow{AC}$

$= \overrightarrow{AO} + \overrightarrow{OC}, \overrightarrow{AD}, \overrightarrow{AO} + \overrightarrow{OD}$

$\overrightarrow{AE} = 2\overrightarrow{AO}, \overrightarrow{AF}$

$= \overrightarrow{AO} + \overrightarrow{OF}, \overrightarrow{AG} = \overrightarrow{AO} + \overrightarrow{OG}$

$\overrightarrow{AH} = \overrightarrow{AO} + \overrightarrow{OH}$

Adding all we get $8\overrightarrow{AO}$

12. (a) The horizontal component of force,

$\vec{F}_x = \left[10 \times \frac{\sqrt{3}}{2} + 20 \times \frac{1}{2} + \frac{20}{\sqrt{2}} - \frac{15}{\sqrt{2}} - \frac{15\sqrt{3}}{2}\right]$

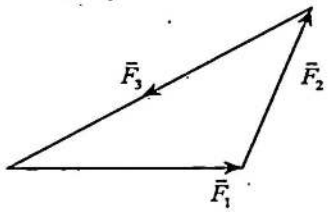
$= 9.25\hat{i}$

The vertical component of force,

$\vec{F}_y = \left[15 \times \frac{1}{2} + 20 \times \frac{\sqrt{3}}{2} + 10 \times \frac{1}{2} - \frac{15}{\sqrt{2}} - \frac{20}{\sqrt{2}}\right] = 5\hat{j}$

$\therefore \vec{F}_R = \vec{F}_x + \vec{F}_y = 9.25\hat{i} + 5\hat{j}$

13. (b)

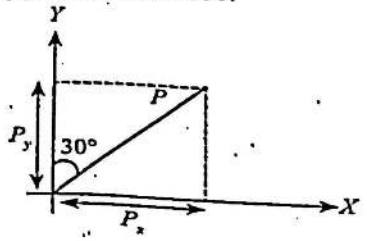


$\therefore$ For equilibrium $F_{net} = 0$

@FAKE_CBSE_X @RAJ_BHNET

14. (d) $\vec{F}=(\vec{F_1}+\vec{F_2}) \Rightarrow |\vec{F_1}|=A, |\vec{F_2}|=\frac{A}{2}$
$\theta=90°$
$\therefore |\vec{F}|=\sqrt{F_1^2+F_2^2+2F_1F_2\cos\theta}$
$|\vec{F}|=\sqrt{A^2+\frac{A^2}{4}}=\frac{A\sqrt{5}}{2}$

15. (d) Let the vector be P.



$P_y=P\cos30°=2\sqrt{3}$
$\Rightarrow P\frac{\sqrt{3}}{2}=2\sqrt{3} \Rightarrow P=4$
Now $P_x=P\sin30°=4\times\frac{1}{2}=2$

16. (a) $\vec{v}=\left(0.5t^2\hat{i}+3t\hat{j}+9\hat{k}\right)$ m/s
At $t=2s$
$\vec{v}=(2\hat{i}+6\hat{j}+9\hat{k})$
Direction cosine along y-axis,
$\cos\theta=\frac{6}{\sqrt{2^2+6^2+9^2}}=\frac{6}{\sqrt{121}}=\frac{6}{11}$
$\therefore \sin\theta=\frac{\sqrt{85}}{11}$
and $\tan\theta=\frac{\sqrt{85}}{6}$
$\theta=\tan^{-1}\left(\frac{\sqrt{85}}{6}\right)$
from y-axis.

17. (d) $\overline{AB}=\overline{AO}+\overline{OB}, \overline{AC}=\overline{AO}+\overline{OC}, \overline{AD}$
$=\overline{AO}+\overline{OD}=2\overline{AO}$
$\Rightarrow \overline{AB}+\overline{AC}+\overline{AD}=4\overline{AO}+\overline{OB}+\overline{OC}$

18. (c) $G\equiv\left(\frac{a}{2},0,\frac{a}{2}\right), \quad H\equiv\left(0,\frac{a}{2},\frac{a}{2}\right)$
$\overline{GH}=-\frac{a}{2}\hat{i}+\frac{a}{2}\hat{j}=\frac{a}{2}(\hat{j}-\hat{i})$

19. (d) As $\vec{P}$ and $\vec{Q}$ are perpendicular their dot product must be zero.
$\vec{P}\cdot\vec{Q}=0$
$\left(\hat{i}+2m\hat{j}+m\hat{k}\right)\cdot\left(4\hat{i}-2\hat{j}+m\hat{k}\right)=0$
$\Rightarrow 4-4m+m^2=0$
$\Rightarrow m=2$

20. [1] For two perpendicular vectors
$\left(a\hat{i}+b\hat{j}+\hat{k}\right)\cdot\left(2\hat{i}-3\hat{j}+4\hat{k}\right)=0$
$2a-3b+4=0$ ...(i)
On solving, $2a-3b=-4$
Also given $3a+2b=7$ ...(ii)
Form (i) & (ii) We get $a=1, b=2$
$\frac{1}{2}=\frac{a}{b}=\frac{x}{2} \Rightarrow x=1$

21. (b)
$|\vec{A}+\vec{B}|=\sqrt{|\vec{A}|^2+|\vec{B}|^2+2|\vec{A}||\vec{B}|\cos\theta}$
$=\sqrt{1+1+2\cos\theta}=2\cos\theta/2$
$|\vec{A}-\vec{B}|=\sqrt{|\vec{A}|^2+|\vec{B}|^2-2|\vec{A}||\vec{B}|\cos\theta}$
$=\sqrt{1-2\cos\theta}=2\sin\theta/2$
$\frac{|\vec{A}+\vec{B}|}{|\vec{A}-\vec{B}|}=\cot\theta/2$
$\Rightarrow |\vec{A}-\vec{B}|=|\vec{A}+\vec{B}|\tan\frac{\theta}{2}$

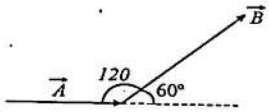
22. (c) According to the question
$|\vec{A}+\vec{B}|=2|\vec{A}-\vec{B}|$ ... (i)
Squaing equation (i) both side.[$\because A=B$]
$|\vec{A}+\vec{B}|^2=(2|\vec{A}-\vec{B}|)^2$
$\Rightarrow 2A^2+2A^2\cos\theta=4(A^2-B^2-A^2\cos\theta)$
$\Rightarrow \cos\theta=\frac{3}{5}$
$\therefore \theta=\cos^{-1}(3/5)$

23. [2] The magnitude of the component of vector A along vector B will be
$=\frac{\vec{A}\cdot\vec{B}}{|\vec{B}|}=\frac{2+6-2}{3}=2$

24. [5] $0=(2\hat{i}+4\hat{j}-2\hat{k})\cdot\left(\frac{\hat{i}+2\hat{j}+\alpha\hat{k}}{\sqrt{1+4+\alpha^2}}\right)$
$0=2+8-2\alpha \Rightarrow \alpha=5$

25. (a) Given that, $\vec{A}.\vec{B}=|\vec{A}\times\vec{B}| \Rightarrow$ AB cos θ = AB sin $\theta \Rightarrow \theta=45°$
$|\vec{A}-\vec{B}|=\sqrt{A^2+B^2-2AB\cos\theta}$
$=\sqrt{A^2+B^2-2AB\times\frac{1}{\sqrt{2}}}$
$=\sqrt{A^2+B^2-\sqrt{2}AB}$

26. (a)



According to diagram,
Angle between $\vec{A}$ and $\vec{B}$, $\theta=60°$
Angle between $\vec{A}$ and $-\vec{B}$, $\theta=120°$
If angle between $\vec{A}$ and $\vec{A}-\vec{B}$ is α
then $\tan\alpha=\frac{|-\vec{B}|\sin\theta}{|\vec{A}|+|-\vec{B}|\cos\theta}$
$=\frac{B\sin120°}{A+B\cos120°}=\frac{B\frac{\sqrt{3}}{2}}{A-\frac{B}{2}}$
$\Rightarrow \tan\alpha=\frac{\sqrt{3}B}{2A-B}$
Hence, the angle between vector $\vec{A}$ and $(\vec{A}-\vec{B})$ is $\tan\alpha=\frac{\sqrt{3}B}{2A-B}$

27. (c) Projection of $\vec{A}$ on $\vec{B}=(\vec{A}.\hat{B})\hat{B}$
$=\left[\left(\hat{i}+\hat{j}+\hat{k}\right).\frac{(\hat{i}+\hat{j})}{\sqrt{2}}\right]\frac{(\hat{i}+\hat{j})}{\sqrt{2}}$
$=\frac{1}{2}(1+1)(\hat{i}+\hat{j})$
$=\left(\frac{1}{\sqrt{2}}+\frac{1}{\sqrt{2}}\right)\frac{(\hat{i}+\hat{j})}{\sqrt{2}}=\hat{i}+\hat{j}$

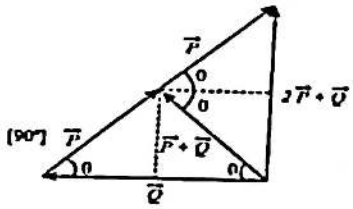
28. (a) $|\vec{A}+\vec{B}|=n|\vec{A}-\vec{B}|$
$\Rightarrow A^2+B^2+2AB\cos\theta$
$=n^2(A^2+B^2-2AB\cos\theta)$
$\Rightarrow \cos\theta(1+n^2)=\frac{2a^2(n^2-1)}{2a^2}$
$[A=B=a]$
$\cos\theta=\frac{n^2-1}{n^2+1}$

29. (c) Given, $|\vec{x}|=|\vec{y}|$ and $|\vec{x}-\vec{y}|=n|\vec{x}+\vec{y}|$
$x^2+y^2-2\vec{x}\cdot\vec{y}=n^2\left(x^2+y^2+2\vec{x}\cdot\vec{y}\right)$
$\left(1-n^2\right)\left(x^2+y^2\right)=\left(1+n^2\right)2\vec{x}\cdot\vec{y}$
$\left(1-n^2\right)\left(x^2+y^2\right)=\left(1+n^2\right)2xy\cos\theta$
$\cos\theta=\frac{1-n^2}{1+n^2}$ $\therefore 2xy=x^2+y^2$
$\theta=\cos^{-1}\left(\frac{n^2-1}{-n^2-1}\right)$

30. (a) According to question the given data is two forces $(\vec{P}+\vec{Q})$ and $(\vec{P}-\vec{Q})$
$\vec{A}=\vec{P}+\vec{Q}$ & $\vec{B}=\vec{P}-\vec{Q}$ & $\vec{P}\perp\vec{Q}$
$\Rightarrow |\vec{A}|=|\vec{B}|=\sqrt{2\left(P^2+Q^2\right)(1+\cos\theta)}$
$\Rightarrow$ For $|\vec{A}+\vec{B}|=\sqrt{3\left(P^2+Q^2\right)} \Rightarrow \theta_1=60°$
$\Rightarrow$ For $|\vec{A}+\vec{B}|=\sqrt{2\left(P^2+Q^2\right)}$
$\Rightarrow \theta_2=90°$

@FAKE_CBSE_KOTA_EDUHUB

31. [90°]

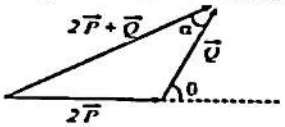


So angle between $(2\vec{P}+\vec{Q})$ and $\vec{Q}$ is 90°

Alternate solution

$|\vec{P}+\vec{Q}|=|\vec{P}|$ $P^2+Q^2+2PQ\cos\theta=P^2$

$\Rightarrow Q+2P\cos\theta=0 \Rightarrow \cos\theta=-\frac{Q}{2P}$



$\tan\alpha=\frac{2P\sin\theta}{2P\cos\theta+Q}=\infty$

$[\because 2P\cos\theta+Q=0]$

$\alpha=90°$

32. (c)

$|\vec{A}_1|=3,\ |\vec{A}_2|=5,\ |\vec{A}_1+\vec{A}_2|=5$

$|\vec{A}_1+\vec{A}_2|=\sqrt{|\vec{A}_1|^2+|\vec{A}_2|^2+2|\vec{A}_1||\vec{A}_2|\cos\theta}$

$5=\sqrt{9+25+2\times3\times5\cos\theta}$

$\Rightarrow \cos\theta=-\frac{3}{10}$

$(2\vec{A}_1+3\vec{A}_2).(3\vec{A}_1-2\vec{A}_2)$

$=6|\vec{A}_1|^2+9\vec{A}_1.\vec{A}_2-4\vec{A}_1\vec{A}_2-6|\vec{A}_2|^2$

$=-118.5$

33. (a) $2|\vec{P}+\vec{Q}|=|\vec{P}+2\vec{Q}|$

$\Rightarrow 13+12\cos\theta=10+6\cos\theta$

$\cos=-\frac{1}{2} \Rightarrow \theta=120°$.

34. (4) $\vec{B}\times\vec{C}=\begin{vmatrix} i & j & k \\ -1 & 4 & 3 \\ -8 & -1 & 3 \end{vmatrix}=15i-21j+33k$

$\vec{A}\cdot(\vec{B}\times\vec{C})$

$=(-xi-6j-2k)\cdot(15i-21j+33k)$

Since, $A\cdot B\times C=0$

$-15x+126-66=0$

$x=4$

35. [4]

$\vec{P}\times\vec{Q}=\begin{vmatrix} i & j & k \\ 3 & \sqrt{3} & 2 \\ 4 & \sqrt{3} & 2.5 \end{vmatrix}=\sqrt{3}\frac{\hat{i}}{2}+\frac{\hat{j}}{2}-\sqrt{3}\hat{k}$

and $\Rightarrow|\vec{P}\times\vec{Q}|=\frac{1}{2}$

$\Rightarrow\frac{\vec{P}\times\vec{Q}}{|\vec{P}\times\vec{Q}|}=\frac{1}{2}\left(\sqrt{3}\frac{\hat{i}}{2}+\frac{\hat{j}}{2}-\sqrt{3}\hat{k}\right)$

$=\frac{1}{4}\left(\sqrt{3}\hat{i}+\hat{j}-2\sqrt{3}\hat{k}\right) \Rightarrow x=4$

36. (c) Given, $|A|\neq0$ $\vec{A}\times\vec{A}=|A||A|\sin0°\hat{n}$

$=|A||A|\sin0°\hat{n}$

$=0$ [Since Angle between the vectors are zero degree]

$\vec{A}\times\vec{A}=0$

37. (b) $\vec{\tau}=\vec{r}\times\vec{F}$

$=\left(2\hat{i}+\hat{j}+2\hat{k}\right)\times\left(3\hat{i}+4\hat{j}-2\hat{k}\right)$

$=\begin{vmatrix} \hat{i} & -\hat{j} & \hat{k} \\ 2 & 1 & 2 \\ 3 & 4 & -2 \end{vmatrix}$

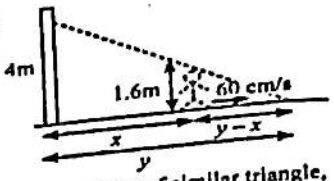
$=\hat{i}(-2-8)-\hat{j}(-4-6)+\hat{k}(8-3)$

$\vec{\tau}=-10\hat{i}+10\hat{j}+5\hat{k}$

38. [180] If angle between them is 180° then

$\vec{P}\times\vec{Q}=\vec{q}\times\vec{P}=0$

39. [40]



From the property of similar triangle,

$\frac{4}{y}=\frac{1.6}{y-x} \Rightarrow x=0.6y$

$\frac{dx}{dt}=0.6\times\frac{dy}{dt} \Rightarrow 60=0.6\times\frac{dy}{dt}$

$\therefore\frac{dy}{dt}=100$ cm/s, i.e., speed of tip of person's shadow w.r.t person $=100-60$ $=40$ cm/s

40. (b) $t=\sqrt{x}+4$, at $t=4, \sqrt{x}=0$

So, $\frac{dt}{dx}=\frac{1}{2\sqrt{x}}$ $\therefore\left(\frac{dx}{dt}\right)_{t=4}$

$=(2\sqrt{x})_{t=4}=0$

41. [3] Direction of P,

$\vec{v}_1=\frac{\vec{A}\times\vec{B}}{|\vec{A}\times\vec{B}|}=\frac{(\hat{i}+\hat{j})\times(\hat{j}+\hat{k})}{|(\hat{i}+\hat{j})\times(\hat{j}+\hat{k})|}=\frac{\hat{i}-\hat{j}+\hat{k}}{\sqrt{3}}$

Direction of Q,

$\vec{v}_2=\frac{\vec{A}\times\vec{C}}{|\vec{A}\times\vec{C}|}=\frac{(\hat{i}+\hat{j})\times(-\hat{j}+\hat{k})}{|(\hat{i}+\hat{j})\times(-\hat{j}+\hat{k})|}=\hat{k}$

Angle between $\vec{v}_1$ and $\vec{v}_2$,

$\cos\theta=\frac{\vec{v}_1.\vec{v}_2}{|\vec{v}_1||\vec{v}_2|}=\frac{\left(\frac{\hat{i}-\hat{j}+\hat{k}}{\sqrt{3}}\right)\cdot(\hat{k})}{(1)\times(1)}=\frac{\frac{1}{\sqrt{3}}}{(1)(1)}=\frac{1}{\sqrt{3}}$

$\Rightarrow\theta=\cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$

Given, $\theta=\cos^{-1}\left(\frac{1}{\sqrt{x}}\right)$

$\therefore x=3$

@FAKE_CBSE_Y @RAJ_EDUNET

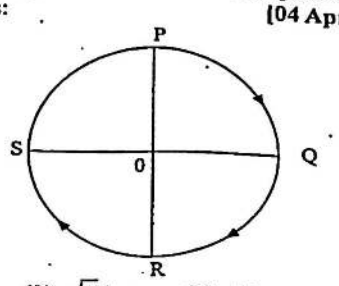
3 Motion in a Straight Line

Scan for Sol.

JEE-Main

Position, Distance and Displacement

1. A cyclist starts from the point P of a circular ground of radius 2 km and travels along its circumference to the point S. The displacement of a cyclist is: **[04 April, 2024 (Shift-II)]**



(a) 6 km (b) $\sqrt{8}$ km (c) 4 km (d) 8 km

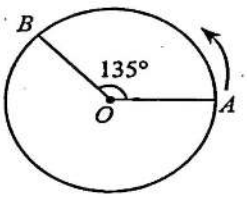
2. A body is moving with constant speed, in a circle of radius 10m. The body completes one revolution in 4s. At the end of 3rd second, the displacement of body (in m) from its starting point is: **[31 Jan, 2023 (Shift-II)]**

(a) 30 (b) 15π (c) 5π (d) $10\sqrt{2}$

3. A particle is moving with constant speed in a circular path. When the particle turns by an angle 90°, the ratio of instantaneous velocity to its average velocity is $\pi : x\sqrt{2}$. The value of x will be **[6 April, 2023 (Shift-I)]**

(a) 2 (b) 5 (c) 1 (d) 7

4. A person moved from A to B on a circular path as shown in figure. If the distance travelled by him is 60 m, then the magnitude of displacement would be: (Given $\cos 135° = -0.7$) **[25 July, 2022 (Shift-I)]**



(a) 42 m (b) 47 m (c) 19 m (d) 40 m

5. The velocity of a particle is $v = v_0 + gt + Ft^2$. Its position is $x = 0$ at $t = 0$; then its displacement after time ($t = 1$) is: **[17 March, 2021 (Shift-II)]**

(a) $v_0 + g + f$ (b) $v_0 + \frac{g}{2} + \frac{F}{3}$

(c) $v_0 + 2g + 3F$ (d) $v_0 + \frac{g}{2} + F$

Speed and Velocity

6. A particle is moving in a straight line. The variation of position 'x' as a function of time 't' is given as $x = (t^3 - 6t^2 + 20t + 15)$ m. The velocity of the body when its acceleration becomes zero is:

(a) 4 m/s (b) 8 m/s (c) 10 m/s (d) 6 m/s

[29 Jan, 2024 (Shift-II)]

7. A physical quantity Q is found to depend on quantities a, b, c by the relation $Q = \frac{a^4 b^3}{c^2}$ The percentage error in a, b and c are 3%, 4% and 5% respectively. Then, the percentage error in Q is:

[31 Jan, 2024 (Shift-I)]

(a) 66% (b) 43% (c) 33% (d) 14%

8. A particle is moving in one dimension (along x axis) under the action of a variable force. It's initial position was 16 m right of origin. The variation of its position (x) with time (t) is given as $x = -3t^3 + 18t^2 + 16t$, where x is in m and t is in s. The velocity of the particle when its acceleration becomes zero is _____ m/s.

[1 Feb, 2024 (Shift-I)]

9. A train starting from rest first accelerates uniformly up to a speed of 80 km/h for time t, then it moves with a constant speed for time $3t$. The average speed of the train for this duration of journey will be (in km/h): **[6 April, 2024 (Shift-I)]**

(a) 80 (b) 70 (c) 30 (d) 40

10. A particle moves in a straight line so that its displacement x at any time t is given by $x^2 = 1 + t^2$. Its acceleration at any time t is x^{-n} where $n =$ _____. **[6 April, 2024 (Shift-II)]**

11. A particle moving in a straight line covers half the distance with speed 6 m/s. The other half is covered in two equal time intervals with speeds 9 m/s and 15 m/s respectively. The average speed of the particle during the motion is: **[09 April, 2024 (Shift-I)]**

(a) 8.8 m/s (b) 10 m/s (c) 9.2 m/s (d) 8 m/s

@NEET_CORE_X @NEETDUNET

12. A car travels a distance of 'x' with speed v_1 and then same distance 'x' with speed v_2 in the same direction. The average speed of the car is: [25 Jan, 2023 (Shift-I)]

(a) $\frac{v_1 v_2}{2(v_1+v_2)}$ (b) $\frac{v_1+v_2}{2}$

(c) $\frac{2x}{v_1+v_2}$ (d) $\frac{2v_1v_2}{v_1+v_2}$

13. The distance travelled by a particle is related to time t as $x = 4t^3$. The velocity of the particle at $t = 5s$ is. [25 Jan, 2023 (Shift-II)]

(a) 40 ms^{-1} (b) 25 ms^{-1} (c) 20 ms^{-1} (d) 8 ms^{-1}

14. A horse rider covers half the distance with 5 *m/s* speed. The remaining part of the distance was travelled with speed 10 *m/s* for half the time and with speed 15 *m/s* for other half of the time. The mean speed of the rider averaged over the whole time of motion is $x/7$ *m/s*. The value of x is _____. [30 Jan, 2023 (Shift-I)]

15. A vehicle travels 4 km with speed of 3 km/h and another 4 km with speed of 5 km/h, then its average speed is: [30 Jan, 2023 (Shift-II)]

(a) 4.25 km/h (b) 3.50 km/h

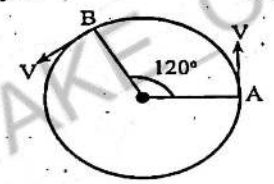
(c) 4.00 km/h (d) 3.75 km/h

16. An object moves with speed v_1, v_2, and v_3 along a line segment AB, BC and CD respectively as shown in figure. Where AB = BC and AD = 3 AB, then average speed of the object will be: [1 Feb, 2023 (Shift-I)]

(a) $\frac{(v_1+v_2+v_3)}{3}$ (b) $\frac{v_1v_2v_3}{3(v_1v_2+v_2v_3+v_3v_1)}$

(c) $\frac{3v_1v_2v_3}{v_1v_2+v_2v_3+v_3v_1}$ (d) $\frac{(v_1+v_2+v_3)}{3v_1v_2v_3}$

17. As shown in the figure, a particle is moving with constant speed π m/s. Considering its motion from A to B, the magnitude of the average velocity is: [6 April, 2023 (Shift-II)]



(a) π *m/s* (b) $\sqrt{3}\,m/s$

(c) $2\sqrt{3}\,m/s$ (d) $1.5\sqrt{3}\,m/s$

18. A person travels x distance with velocity v_1 and then x distance with velocity v_2 in the same direction. The average velocity of the person is v, then the relation between v, v_1 and v_2 will be: [10 April, 2023 (Shift-II)]

(a) $v = v_1 + v_2$ (b) $v = \frac{v_1+v_2}{2}$

(c) $\frac{2}{v} = \frac{1}{v_1} + \frac{1}{v_2}$ (d) $\frac{1}{v} = \frac{1}{v_1} + \frac{1}{v_2}$

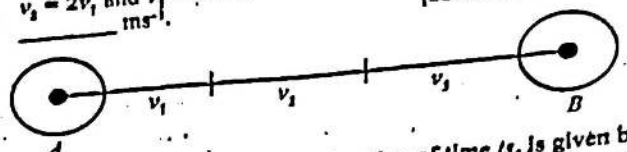
19. The distance travelled by an object in time t is given by $s = (2.5)t^2$. The instantaneous speed of the object at $t = 5$ s will be: [13 April, 2023 (Shift-II)]

(a) 12.5 ms^{-1} (b) 62.5 ms^{-1} (c) 5 ms^{-1} (d) 25 ms^{-1}

20. The position of a particle related to time is given by $x = (5t^2 - 4t + 5)$m. The magnitude of velocity of the particle at $t = 2$s will be: [15 April, 2023 (Shift-I)]

(a) 10 ms^{-1} (b) 14 ms^{-1} (c) 16 ms^{-1} (d) 06 ms^{-1}

21. A car covers AB distance with first one-third at velocity v_1 ms^{-1}, second one-third at v_2 ms^{-1} and last one-third at v_3 ms^{-1}. If $v_2 = 3v_1$, $v_3 = 2v_1$ and $v_1 = 11$ ms^{-1} then the average velocity of the car is _____ ms^{-1}. [28 June, 2022 (Shift-II)]



22. The position of a particle as a function of time t, is given by $x(t) = at + bt^2 - ct^3$ where a, b and c are constants. When the particle attains zero acceleration, then its velocity will be: [9 April, 2019 (Shift-II)]

(a) $a + \frac{b^2}{4c}$ (b) $a + \frac{b^2}{c}$ (c) $a + \frac{b^2}{2c}$ (d) $a + \frac{b^2}{3c}$

23. A particle is moving with speed $v = b\sqrt{x}$ along positive x-axis. Calculate the speed of the particle at time $t = \tau$ (assume that the particle is at origin at $t = 0$) [12 April, 2019 (Shift-II)]

(a) $\frac{b^2\tau}{4}$ (b) $\frac{b^2\tau}{2}$ (c) $b^2\tau$ (d) $\frac{b^2\tau}{\sqrt{2}}$

Constant Acceleration

24. A bullet is fired into a fixed target looses one third of its velocity after travelling 4 cm. It penetrates further D × 10^{-3} m before coming to rest. The value of D is: [27 Jan, 2024 (Shift-II)]

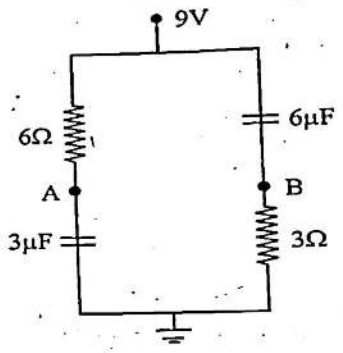
(a) 2 (b) 5 (c) 3 (d) 4

25. A body falling under gravity covers two points A and B separated by 80 cm in 2s. The distance of upper point A from the starting point is _____ m (use g = 10 ms^{-2}) [27 Jan, 2024 (Shift-II)]

26. A stone of mass 900g is tied to a string and moved in a vertical circle of radius 1m making 10 rpm. The tension in the string, when the stone is at the lowest point is (if $\pi^2 = 9.8$ and g = 9.8 m/s^2) [29 Jan, 2024 (Shift-I)]

(a) 97 N (b) 9.8 N (c) 8.82 N (d) 17.8 N

27. In the given figure, the charge stored in 6μF capacitor, when points A and B are joined by a connecting wire is _____μC. [30 Jan, 2024 (Shift-I)]



@FAKE CASE X @RANDOM

28. A particle initially at rest starts moving from reference point. $x = 0$ along x-axis, with velocity v that varies as $v = 4\sqrt{x}\, m/s$. The acceleration of the particle is _____ ms^{-2}. **[1 Feb, 2024 (Shift-II)]**

29. A body travels 102.5 m in nth second and 115.0 m in $(n+2)$th second. The acceleration is: **[04 April, 2024 (Shift-I)]**
(a) 9 m/s² (b) 6.25 m/s² (c) 12.5 m/s² (d) 5 m/s²

30. A bus moving along a straight highway with speed of 72 km/h is brought to halt within 4s after applying the brakes. The distance travelled by the bus during this time (Assume the retardation is uniform) is _____m. **[04 April, 2024 (Shift-II)]**

31. A body moves on a frictionless plane starting from rest. If S_n is distance moved between $t = n-1$ and $t = n$ and S_{n-1} is distance moved between $t = n-2$ and $t = n-1$, then the ratio $\frac{S_{n-1}}{S_n}$ is $\left(1-\frac{2}{x}\right)$ for $n = 10$. The value of x is .....
[05 April, 2024 (Shift-I)]

32. A body projected vertically upwards with a certain speed from the top of a tower reaches the ground in t1. If it is projected vertically downwards from the same point with the same speed, it reaches the ground in t2. Time required to reach the ground, if it is dropped from the top of the tower, is: **[06 April, 2024 (Shift-II)]**
(a) $\sqrt{t_1 t_2}$ (b) $\sqrt{t_1 - t_2}$ (c) $\sqrt{\frac{t_1}{t_2}}$ (d) $\sqrt{t_1 + t_2}$

33. Two cars are travelling towards each other at speed of 20 m s^{-1} each. When the cars are 300 m apart, both the drivers apply brakes and the cars retard at the rate of 2 m s^{-2}. The distance between them when they come to rest is: **[09 April, 2024 (Shift-II)]**
(a) 200 m (b) 50 m (c) 100 m (d) 25 m

34. For a train engine moving with speed of 20 ms^{-1}. the driver must apply brakes at a distance of 500m before the station for the train to come to rest at the station. If the brakes were applied at half of this distance, the train engine would cross the station with speed $\sqrt{x}\, ms^{-1}$. The value of x is _____.
(Assuming same retardation is produced by brakes)
[1 Feb, 2023 (Shift-II)]

35. A particle starts with an initial velocity of 10.0ms^{-1} along x-direction and accelerates uniformly at the rate of 2.0 ms^{-2}. The time taken by the particle to reach the velocity of 60.0 ms^{-1} is
[6 April, 2023 (Shift-II)]
(a) 6s (b) 3s (c) 30s (d) 25s

36. A small toy starts moving from the position of rest under a constant acceleration. If it travels a distance of 10 m in t s, the distance travelled by the toy in the next t s will be:
[29 June, 2022 (Shift-II)]
(a) 10 m (b) 20 m (c) 30 m (d) 40 m

37. A car is moving with speed of 150 km/h and after applying the break it will move 27m before it stops. If the same car is moving with a speed of one third the reported speed then it will stop after travelling _____ m distance. **[25 July, 2022 (Shift-I)]**

38. A particle is moving in a straight line such that its velocity is increasing at 5 ms^{-1} per meter. The acceleration of the particle is _____ms^{-2} at a point where its velocity is 20 ms^{-1}.
[25 July, 2022 (Shift-II)]

39. An engine of a train, moving with uniform acceleration, passes the signal - post with velocity u and the last compartment with velocity v. The velocity with which middle point of the train passes the signal post is :
[25 Feb, 2021 (Shift-I)]
(a) $\frac{u+v}{2}$ (b) $\sqrt{\frac{v^2+u^2}{2}}$ (c) $\frac{v-u}{2}$ (d) $\sqrt{\frac{v^2-u^2}{2}}$

40. In a car race on straight road, car A takes a time 't' less than car B at the finish and passes finishing point with a speed 'V' more than that of car B. Both the cars start from rest and travel with constant acceleration a_1 and a_2 respectively. Then 'v' is equal to
[9 Jan, 2019 (Shift-II)]
(a) $\frac{2a_1a_1}{a_1+a_2}t$ (b) $\sqrt{2a_1a_2}t$ (c) $\sqrt{a_1a_2}\,t$ (d) $\frac{a_1+a_2}{2}t$

Motion Under Gravity

41. A tennis ball is dropped on to the floor from a height of 9.8m. It rebounds to a height 5.0 m. Ball comes in contact with the floor for 0.2 s. The average acceleration during contact is _____ ms^{-2}
[Given g = 10 ms^{-1}] **[29 Jan, 2023 (Shift-I)]**

42. A ball is thrown vertically upward with an initial velocity of 150 m/s. The ratio of velocity after 3s and 5s is $\frac{x+1}{x}$. The value of x is _____.
Take (g = 10 m/s²). **[12 April, 2023 (Shift-1)]**
(a) 6 (b) 5 (c) –5 (d) 10

43. From the top of a tower, a ball is thrown vertically upward which reaches the ground in 6s. A second ball thrown vertically downward from the same position with the same speed reaches the ground in 1.5s. A third ball released, from the rest from the same location, will reach the ground in _____s. **[24 June, 2022 (Shift-I)]**

44. An object of mass 5 kg is thrown vertically upwards from the ground. The air resistance produces a constant retarding force of 10 N throughout the motion. The ratio of time of ascent to the time of descent will be equal to: [Use $g = 10$ ms^{-2}].
[24 June, 2022 (Shift-II)]
(a) 1 : 1 (b) $\sqrt{2}:\sqrt{3}$ (c) $\sqrt{3}:\sqrt{2}$ (d) 2 : 3

45. An object is thrown vertically upwards. At its maximum height, which of the following quantity becomes zero?
[26 June, 2022 (Shift-I)]
(a) Momentum (b) Potential Energy
(c) Acceleration (d) Force

46. A ball of mass 0.5 kg is dropped from the height of 10 m. The height, at which the magnitude of velocity becomes equal to the magnitude of acceleration due to gravity, is _____m. [Use $g = 10$ m/s²]
[26 June, 2022 (Shift-I)]

47. A ball is projected vertically upward with an initial velocity of 50 ms^{-1} at $t = 0$ s. At $t = 2$ s, another ball is projected vertically upward with same velocity. At $t =$ _____ s, second ball will meet the first ball ($g = 10$ ms^{-2}). **[26 June, 2022 (Shift-II)]**

48. Two balls A and B placed at the top of 180m tall tower. Ball A is released from the top at $t = 0$s. Ball B is thrown vertically down with an initial velocity 'u' at $t = 2$s. After a certain time, both balls meet 100m above the ground. Find the value of 'u' in ms^{-1}. [use $g = 10$ ms^{-2}]: **[29 June, 2022 (Shift-I**
(a) 10 (b) 15 (c) 20 (d) 30

@FAKE CBSE KEY @RAJ EDUCAT

49. A NCC parade is going at a uniform speed of 9 km/h under a mango tree on which a monkey is sitting at a height of 19.6 m. At any particular instant, the monkey drops a mango. A cadet will receive the mango whose distance from the tree at time of drop is: (Given $g = 9.8\ m/s^2$) [28 July, 2022 (Shift-I)]

(a) 5 m (b) 10 m (c) 19.8 m (d) 24.5 m

50. A ball is thrown vertically upwards with a velocity of 19.6 ms^{-1} from the top of a tower. The ball strikes the ground after 6 s. The height from the ground up to which the ball can rise will be $\left(\frac{k}{5}\right)m$. The value of k is _____
(use $g = 9.8\ m/s^2$) [28 July, 2022 (Shift-II)]

51. A ball is thrown up vertically with a certain velocity so that, it reaches a maximum height h. Find the ratio of the times in which it is at height $\frac{h}{3}$ while going up and coming down respectively. [29 July, 2022 (Shift-I)]

(a) $\frac{\sqrt{2}-1}{\sqrt{2}+1}$ (b) $\frac{\sqrt{3}-\sqrt{2}}{\sqrt{3}+\sqrt{2}}$ (c) $\frac{\sqrt{3}-1}{\sqrt{3}+1}$ (d) $\frac{1}{3}$

52. A juggler throws ball vertically upwards with same initial velocity in air. When the first ball reaches its highest positions, he throws the next ball. Assuming the juggler throws n balls per second, the maximum height the balls can reach is [29 July, 2022 (Shift-II)]

(a) $g/2n$ (b) $2gn$ (c) g/n (d) $g/2n^2$

53. A ball is released from a height h. If t_1 and t_2 be the time required to complete first half and second half of the distance respectively. Then, choose the correct relation between t_1 and t_2. [29 July, 2022 (Shift-II)]

(a) $t_1 = \left(\sqrt{2}\right)t_2$ (b) $t_1 = \left(\sqrt{2}-1\right)t_2$

(c) $t_2 = \left(\sqrt{2}+1\right)t_1$ (d) $t_2 = \left(\sqrt{2}-1\right)t_1$

54. A balloon was moving upwards with a uniform velocity of 10 m/s. An object of finite mass is dropped from the balloon when it was at a height of 75m from the ground level. The height of the balloon from the ground when object strikes the ground was around: (takes the value of g as 10 m/s^2) [25 July, 2021 (Shift-II)]

(a) 250 m (b) 300 m (c) 200 m (d) 125 m

55. A stone is dropped from the top of a building. When it crosses a point 5m below the top, another stone starts to fall from a point 25m below the top. Both stones reach the bottom of building simultaneously. The height of the building is: [25 Feb, 2021 (Shift-II)]

(a) 35 m (b) 45 m (c) 50 m (d) 25 m

56. Two spherical balls having equal masses with radius of 5 cm each are thrown upwards along the same vertical direction at an interval of 3s with the same initial velocity of 35 m/s, then these balls collide at a height of _____ m. (Take $g = 10\ m/s^2$) [26 Aug, 2021 (Shift-I)]

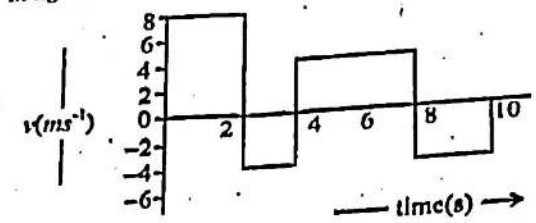
57. Water drops are falling from a nozzle of a shower onto the floor, from a height of 9.8m. The drops fall at a regular interval of time. When the first drop strikes the floor, at that instant, the third drop begins to fall. Locate the position of second drop from the floor when the first drop strikes the floor. [27 Aug, 2021 (Shift-II)]

(a) 7.35 m (b) 2.45 m (c) 2.94 m (d) 4.18 m

58. A ball is dropped form the top of a 100 m high tower on a planet. In the last 1/2 s before hitting the ground, it covers a distance of 19 m. Acceleration due to gravity (in ms^{-2}) near the surface on that planet is _____. [8 Jan, 2020 (Shift-II)]

Graphs

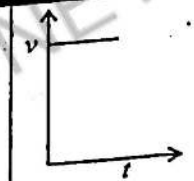
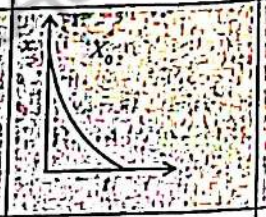
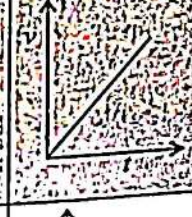
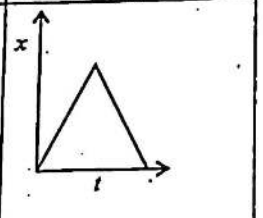
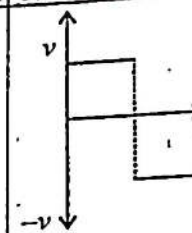
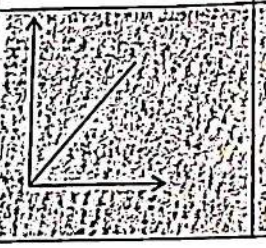
59. The velocity time graph of a body moving in a straight line is shown in figure.



The ratio of displacement to distance travelled by the body in time 0 to 10 s is [24 Jan, 2023 (Shift-II)]

(a) 1 : 1 (b) 1 : 4 (c) 1 : 2 (d) 1 : 3

60. Match Column-I with Column-II:

Column-I (x-t graphs)	Column-II (v-t graphs)
A.	I. 
B. 	II. 
C. 	III. 
D. 	IV.

Choose the correct answer from the options given below: [30 Jan, 2023 (Shift-I)]

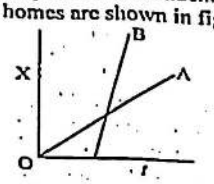
(a) A- II, B-IV, C-III, D-I (b) A- I, B-II, C-III, D-IV

(c) A- II, B-III, C-IV, D-I (d) A- I, B-III, C-IV, D-II

PHYSICS @ RAJ EDUMET

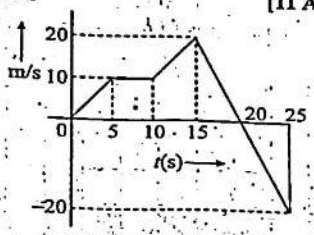
61. Given below are two statements:
Statement-I: Area of the velocity-time graph gives the distance travelled by the body in a given time.
Statement-II: Area under acceleration- time graph is equal to the change in velocity- in the given time.
In the light of given statements, choose the correct answer from the options given below. **[8 April, 2023 (Shift-II)]**
(a) Both Statement-I and Statement-II are true.
(b) Statement-I is correct but Statement-II is false.
(c) Statement-I is incorrect but Statement-II is true.
(d) Both Statement-I and Statement-II are False.

62. The position-time graphs for two students A and B returning from the school to their homes are shown in figure:



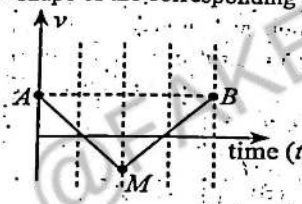
(A) A lives closer to the school
(B) B lives closer to the school
(C) A takes lesser time to reach home
(D) A travels faster than B
(E) B travels faster than A **[10 April, 2023 (Shift-1)]**
Choose the correct answer from the options given below:
(a) (A) and (E) only (b) (B) and (E) only
(c) (A), (C) and (E) only (d) (A), (C) and (D) only

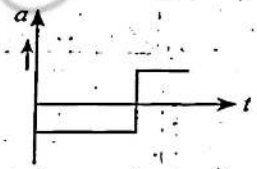
63. From the $v - t$ graph shown. The ratio of distance to displacement in 25 s of motion **[11 April, 2023 (Shift-I)]**

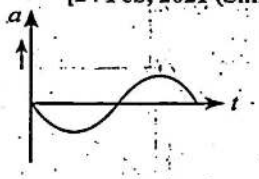


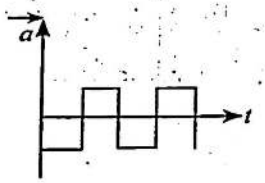
(a) $\frac{3}{5}$ (b) $\frac{1}{2}$ (c) $\frac{5}{3}$ (d) 1

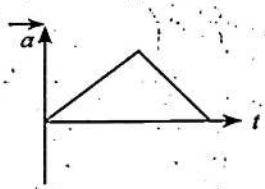
64. If the velocity-time graph has the shape AMB, what would be the shape of the corresponding acceleration-time graph? **[24 Feb, 2021 (Shift-I)]**



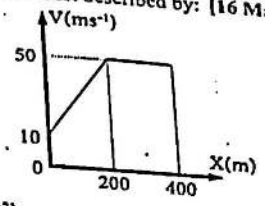
(a) 

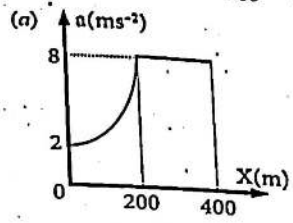
(b) 

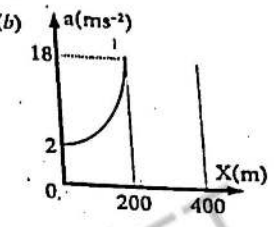
(c) 

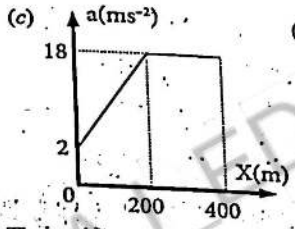
(d) 

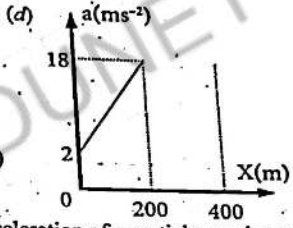
65. The velocity- displacement graph describing the motion of a bicycle is shown in the figure. The acceleration-displacement graph of the bicycle's motion is best described by: **[16 March, 2021 (Shift-I)]**



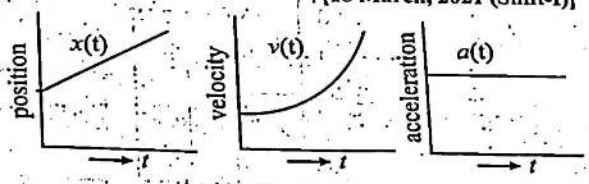
(a) 

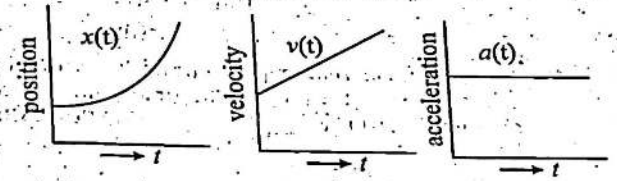
(b) 

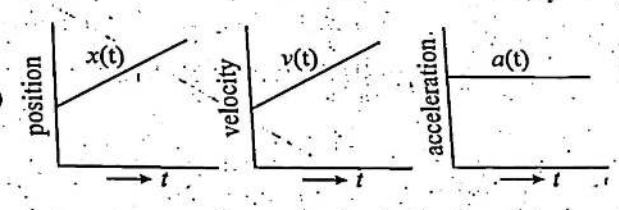
(c) 

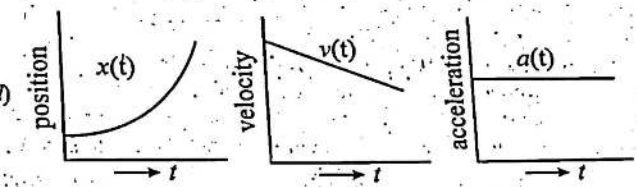
(d) 

66. The position, velocity and acceleration of a particle moving with a constant acceleration can be represented by **[18 March, 2021 (Shift-I)]**

(a) 

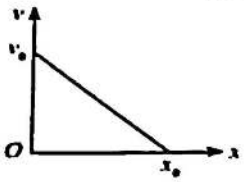
(b) 

(c) 

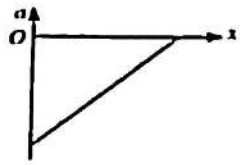
(d) 

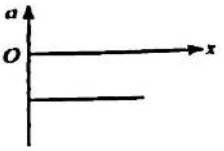
@FREE_CBSE_KA_FREEDUNET

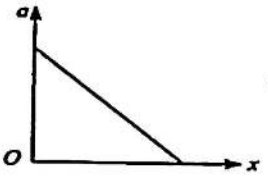
67. The velocity - displacement graph of a particle is shown in the figure.
[18 March, 2021 (Shift-II)]

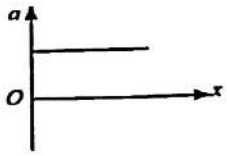


The acceleration - displacement graph of the same particle is represented by:

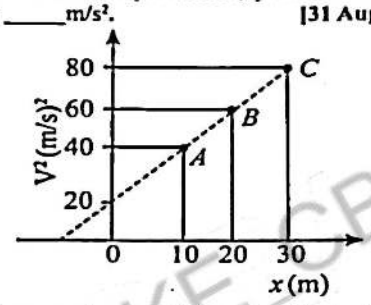
(a) 

(b) 

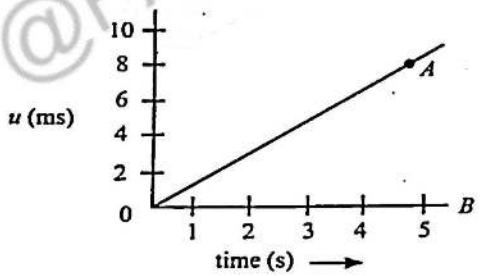
(c) 

(d) 

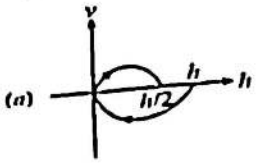
68. A particle is moving with constant acceleration 'a'. Following graph shows v^2 versus x (displacement) plot. The acceleration of the particle is _____ m/s².
[31 Aug, 2021 (Shift-II)]

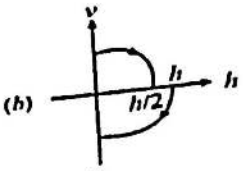


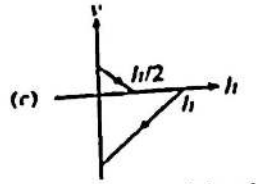
69. The speed versus time graph for a particle is shown in the figure. The distance travelled (in m) by the particle during the time interval $t = 0$ to $t = 5$ s will be _____.
[3 Sep, 2020 (Shift-II)]

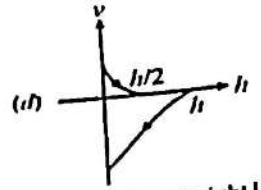


70. A tennis ball is released from a height h and after freely falling on a wooden floor it rebounds and reaches height $h/2$. The velocity versus height of the ball during its motion may be represented graphically by (graph are drawn schematically and on not to scale).
[4 Sep, 2020 (Shift-I)]

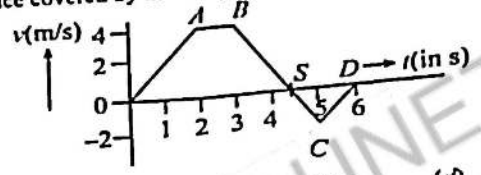
(a) 

(b) 

(c) 

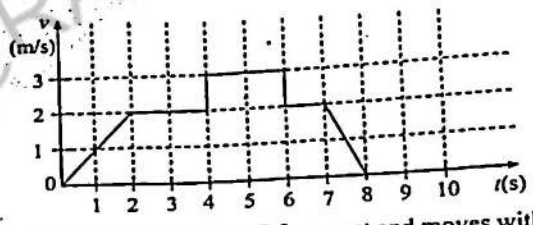
(d) 

71. The velocity (v) and time (t) graph of a body in a straight line motion is shown in the figure. The point S is at 4.333 second. The total distance covered by the body in 6 s is
[5 Sep, 2020 (Shift-II)]

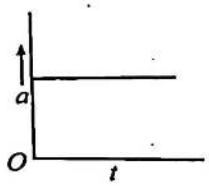


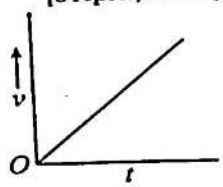
(a) $\frac{37}{3}$ m (b) 11 m (c) 12 m (d) $\frac{49}{4}$ m

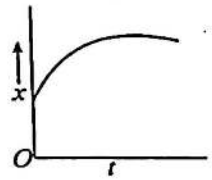
72. A particle starts from the origin at time $t = 0$ and moves along the positive x-axis. The graph of velocity with respect to time is shown in figure. What is the position of the particle at time $t = 5s$?
[10 Jan, 2019 (Shift-II)]

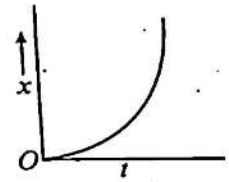


73. A particle starts from origin O from rest and moves with a uniform acceleration along the positive x-axis. Identify the figure that is not correctly representing the motion qualitatively.
(a = acceleration, v = velocity, x = displacement, t = time)
[8 April, 2019 (Shift-II)]

(A) 

(B) 

(C) 

(D) 

(a) (A), (B), (C) (b) (A)
(c) (C) (d) (B), (C)

(a) 10 m (b) 6 m (c) 3 m (d) 9 m

@AKE_CBSE X @RAKEDUNET

Variable Acceleration

74. The relation between time t and distance x for a moving body is given as $t = mx^2 + nx$, where m and n are constants. The retardation of the motion is: (Where v stands for velocity)
[25 July, 2021 (Shift-II)]
(a) $2n^2v^2$ (b) $2mnv^3$ (c) $2mv^3$ (d) $2nv^3$

75. The instantaneous velocity of a particle moving in a straight line is given as $v = \alpha t + \beta t^2$, where α and β are constants. The distance travelled by the particle between 1s and 2s is:
[25 July, 2021 (Shift-II)]
(a) $\frac{\alpha}{2}+\frac{\beta}{3}$ (b) $\frac{3}{2}\alpha+\frac{7}{3}\beta$
(c) $\frac{3}{2}\alpha+\frac{7}{2}\beta$ (d) $3\alpha + 7\beta$

76. The distance x covered by a particle in one dimensional motion varies with time t as $x^2 = at^2 + bt + c$. If the acceleration of the particle depends on x as x^{-n}, where n is an integer, the value of n is _____.
[9 Jan, 2020 (Shift-I)]

One Dimensional Relative Motion

77. Train A is moving along two parallel rail tracks towards north with speed 72 km/h and train B is moving towards south with speed 108 km/h. Velocity of train B with respect to A and velocity of ground with respect to B are (in ms^{-1}):
[1 Feb, 2024 (Shift-II)]
(a) –30 and 50 (b) –50 and –30
(c) –50 and 30 (d) 50 and –30

78. Two trains 'A' and 'B' of length 'l' and '$4l$' are travelling into a tunnel of length 'L' in parallel tracks from opposite directions with velocities 108 km/h and 72 km/h, respectively. If train 'A' takes 35s less time than train 'B' to cross the tunnel then, length 'L' of tunnel is (Given $L = 60l$)
[13 April, 2023 (Shift-I)]
(a) 1200 m (b) 2700 m (c) 1800 m (d) 900 m

79. A passenger sitting in a train A moving at 90 km/h observes another train B moving in the opposite direction for 8 s. If the velocity of the train B is 54 km/h, then length of train B is:
[13 April, 2023 (Shift-II)]
(a) 80 m (b) 200 m (c) 120 m (d) 320 m

80. Two buses P and Q start from a point at the same time and move in a straight line and their positions are represented by $X_P(t) = \alpha t + \beta t^2$ and $X_Q(t) = ft - t^2$. At what time, both the buses have same velocity?
[25 June, 2022 (Shift-II)]
(a) $\frac{\alpha - f}{1+\beta}$ (b) $\frac{\alpha + f}{2(\beta-1)}$ (c) $\frac{\alpha + f}{2(1+\beta)}$ (d) $\frac{f-\alpha}{2(1+\beta)}$

81. Train A and train B are running on parallel tracks in opposite directions with speeds of 36 km/hour and 72 km/hour, respectively, A person is walking in train A in the direction opposite to its motion with a speed of 1.8 km/hour. Speed (in ms^{-1}) of this person as observed from train B will be close to: (take the distance between the tracks as negligible)
[2 Sep, 2020 (Shift-I)]
(a) 28.5 ms^{-1} (b) 31.5 ms^{-1} (c) 30.5 ms^{-1} (d) 29.5 ms^{-1}

82. A passenger train of length 60 m travels at a speed of 80 km/hr. Another freight train of length 120 m travels at a speed of 30 km/hr. The ratio of times taken by the passenger train to completely cross the freight train when: (*i*) they are moving in the same direction, and (*ii*) in the opposite direction is:
[12 Jan, 2019 (Shift-I)]
(a) $\frac{11}{5}$ (b) $\frac{5}{2}$ (c) $\frac{3}{2}$ (d) $\frac{25}{11}$

JEE-Advanced

Position, Distance and Displacement

Single Correct

1. A small block slides without friction down an inclined plane starting from rest. Let S_n be the distance travelled from $t = n - 1$ to $t = n$. Then, $\frac{S_n}{S_{n+1}}$ is
(IIT-JEE 2004)
(a) $\frac{2n-1}{2n}$ (b) $\frac{2n+1}{2n-1}$ (c) $\frac{2n-1}{2n+1}$ (d) $\frac{2n}{2n+1}$

2. A particle of mass m moves on the x-axis as follows: it starts from rest at $t = 0$ from the point $x = 0$ and comes to rest at $t = 1$ at the point $x = 1$ No other information is available about its motion at intermediate times ($0 < t < 1$). If α denotes the instantaneous acceleration of the particle, then
(IIT-JEE 1993,1984)
(a) α cannot remain positive for all t in the interval $0 \le t \le 1$
(b) $|\alpha|$ cannot exceed 2 at any point in its path
(c) $|\alpha|$ must be ≥ 4 at some point or points in its path
(d) α must change sign during the motion, but no other assertion can be made with the information given

Speed and Velocity

Subjective

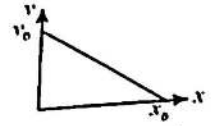
3. A particle of mass 10^{-2} kg is moving along the positive X-axis under the influence of a force $F(x) = -k/2x^2$ where $k = 10^{-2}$ Nm^2. At time $t = 0$, it is at $x = 1.0$ m and its velocity $v = 0$
(a) Find its velocity when it reaches $x = 0.5$ m.
(b) Find the time at which it reaches $x = 0.25$ m. (IIT-JEE 1998)

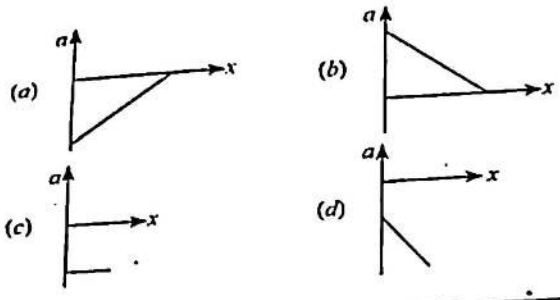
@FAKE_CBSE_X_@FAKE_DUMMY

Constant Acceleration

Single Correct

4. The given graph shows the variation of velocity with displacement. Which one of the graph given below correctly represents the variation of acceleration with displacement? **(JEE Adv. 2015)**



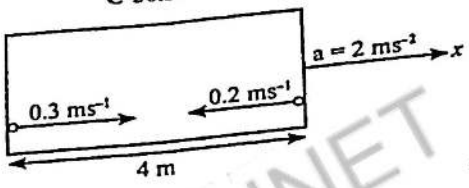


One Dimensional Relative Motion

Numerical Types

5. A rocket is moving in a gravity free space with a constant acceleration of 2 ms^{-2} along +x direction (see figure). The length of a chamber inside the rocket is 4 m. A ball is thrown from the left end of the chamber in +x direction with a speed of 0.3 ms^{-1} relative to the rocket. At the same time, another ball is thrown in –x direction with a speed of 0.2 ms^{-1} from its right end relative to the rocket. The time in seconds when the two balls hit each.

C-50.58 W-41.08 UA-8.34 (JEE Adv. 2014)



@FAKE_CBSE X @RAJ_EDUNET

ANSWER KEY

JEE-Main

1. (b)	2. (d)	3. (a)	4. (b)	5. (b)	6. (b)	7. (c)	8. [52]	9. (b)	10. [3]
11. (d)	12. (d)	13. (a)	14. [50]	15. (d)	16. (c)	17. (d)	18. (c)	19. (d)	20. (c)
21. [18]	22. (d)	23. (b)	24. (Bonus)	25. [45.00]	26. (b)	27. [36]	28. [8]	29. (b)	30. [40]
31. [19]	32. (a)	33. (c)	34. [200]	35. (d)	36. (c)	37. [3]	38. [100]	39. (b)	40. (c)
41. [120]	42. (b)	43. [3]	44. (b)	45. (a)	46. [5]	47. [6]	48. (d)	49. (a)	50. [392]
51. (b)	52. (d)	53. (d)	54. (d)	55. (b)	56. [50]	57. (a)	58. [8]	59. (d)	60. (a)
61. (c)	62. (a)	63. (c)	64. (a)	65. (d)	66. (b)	67. (a)	68. [1]	69. [20]	70. (b)
71. (a)	72. (d)	73. (c)	74. (c)	75. (b)	76. [3]	77. (c)	78. (c)	79. (d)	80. (d)
81. (d)	82. (a)								

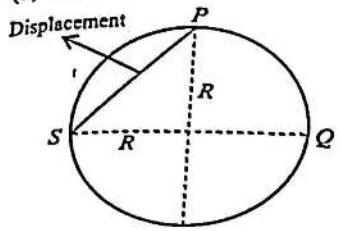
JEE-Advanced

1. (c)	2. (c)	4. (a)	5. [8]

EXPLANATIONS

JEE-Main

1. (b) Given: R = 2km

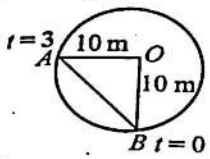


$\therefore$ Displacement = PS

$\sqrt{R^2+R^2} = R\sqrt{2} = 2 = \sqrt{8}$ km

2. (d) Angle rotated by the moving body

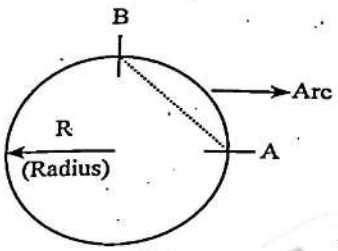
$\theta = \frac{3}{4}\times 2\pi = \frac{3\pi}{2}$



|Displacement| = $AB = \sqrt{2}R$

$= 10\sqrt{2}$ m

3. (a)



Arc length $= 2\pi\left(\frac{R}{4}\right)$

$= \frac{\pi R}{2}$

Let instantaneous velocity be v.

Time to cover arc length

$t = \frac{\text{Arc length}}{v} = \frac{\pi R}{2v}$

$AB = R\sqrt{2}$

Average velocity,

$\langle v \rangle = \frac{AB}{t} = \frac{R\sqrt{2}(2v)}{\pi R} = \frac{2\sqrt{2}v}{\pi}$

$\Rightarrow \frac{v}{\langle v \rangle} = \frac{\pi}{2\sqrt{2}}$.

4. (b) Distance moved, AB = 60 m

$\because (\theta) = \frac{\text{Arc}(AB)}{\text{radius}(R)} = \frac{3\pi}{4} = \frac{60}{R}$

$R = \frac{60\times 4}{3\pi} = \frac{80}{\pi} m$

Displacement $= \sqrt{R^2+R^2-2R^2\cos 135}$

$\{\because \cos 135 = \cos(90+45) = \sin 45^\circ = -0.7\}$

$= \sqrt{2R^2-2R^2(-0.7)} = \sqrt{3.4R^2}$

$= \sqrt{3.4\left(\frac{80}{4}\right)^2}$

≈ 47 m

5. (b) $V = V_0 + gt + Ft^2$

$\frac{dx}{dt} = V_0 + gt + Ft^2$

$\Rightarrow \int_{x=0}^{x} dx = \int_{t=0}^{t=1}\left(V_0 + gt + Ft^2\right)dt$

$x = \left[V_0 t + \frac{gt^2}{2} + \frac{Ft^3}{3}\right]_{t=0}^{t=1}$

$\Rightarrow x = V_0 + \frac{g}{2} + \frac{F}{3}$

6. (b) $x = t^3 - 6t^2 + 20t + 15$

The velocity of the body

$\frac{dx}{dt} = v = 3t^2 - 12t + 20$

The acceleration of the body

$\frac{dv}{dt} = a = 6t - 12$

When $a = 0$

$6t - 12 = 0$; $t = 2$ sec

At $t = 2$ sec

The velocity of the body when its acceleration becomes zero

$v = 3(2)^2 - 12(2) + 20$

$v = -8$ m/s

7. (c) $Q = \frac{a^4b^3}{c^2}$

By using the percentage error formula,

$\frac{\Delta Q}{Q} = 4\frac{\Delta a}{a} + \frac{\Delta b}{b} + 2\frac{\Delta c}{c}$

$\frac{\Delta Q}{Q} = 100 = 4\left(\frac{\Delta a}{a}\times 100\right) + 3\left(\frac{\Delta b}{b}\times 100\right) + 2\left(\frac{\Delta c}{c}\times 100\right)$

% error in $Q = 4\times 3\% + 3\times 4\% + 2\times 5\%$

$= 12\% + 12\% + 10\% = 34\%$

8. [52]

Given: $x = 3t^3 + 18t^2 + 16t$

$v = -9t^2 + 36 + 16$

$a = \frac{dv}{dt} = -18t + 36$

$a = 0$ at $t = 2$s

$v = -9(2)^2 + 36\times 2 + 16$

$v = 52$ m/s

9. (b) Average speed

$= \frac{\text{total distance travelled}}{\text{total time taken}}$

$= \frac{\frac{80\times t}{2} + 80\times 3t}{4t} = 70$ km/hr.

10. [3] $x^2 = 1 + t^2$

Differenciating

$2x\frac{dx}{dt} = 2t$

$xv = t$

Again, differenciating

$x\frac{dv}{dt} + v\frac{dx}{dt} = 1$

$x.a + v^2 = 1$

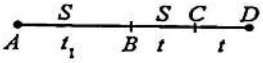
$a = \frac{1-v^2}{x} = \frac{1-t^2/x^2}{x}$

$a = \frac{1}{x^3} = x^{-3}$

11. (d) Given,

The particle is covering half of the distance with 6m/s

Other half distance in two equal time intervals with speed of 9m/s and 15 m/s



$BD \Rightarrow S = 9t + 15t = 24t$

$AB \Rightarrow S = 6t_1 = 24t \Rightarrow t_1 = 4t$

$\langle \text{speed} \rangle = \frac{\text{dist.}}{\text{time}} = \frac{48t}{2t + t_1}$

$= \frac{48t}{2t+4t} \Rightarrow \frac{48t}{6t} \Rightarrow 8$ m/s

12. (d) Average Speed

$= \frac{\text{Total distance of the car}}{\text{Total time}}$

$= \frac{x+x}{\frac{x}{v_1} + \frac{x}{v_2}} = \frac{2v_1v_2}{v_1+v_2}$

PEAKE_CBSE_@RAJ_EDUNET

13. (a) $\because x = 4t^2$

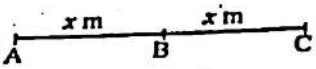
Differentiating both sides

$\frac{dx}{dt} = 8t$

At $t = 5$sec

$v = 8 \times 5 = 40$ m/s.

14. [50]



$t_{AB} = \frac{x}{5 m/s}$

In motion BC

$x = d_1 + d_2$

where d_1 and d_2 we the distance travelled with 10 m/s and 15 m/s respectively in equal time intervals $\frac{t}{2}$ each

$d_1 = \frac{10t}{2}, d_2 = \frac{15t}{2}$

$d_1 + d_2 = x = \frac{t}{2}(10+15) = \frac{25t}{2}$

$\langle v \rangle = \frac{2x}{\frac{x}{5} + \frac{2x}{25}} = \frac{2 \times 25}{5+2} = \frac{50}{7} m/s$

15. (d) Time for first part of motion $t_1 = \frac{4}{3}$

and time for second part of motion $t_2 = \frac{4}{5}$

Total Time $t = t_1 + t_2 = \frac{32}{15}$

$\therefore V_{avg} = \frac{15}{4} = 3.75$ km/h

16. (c) Given $AB = x$ and $BC = x$

$\because AB + BC + CD = 3x$

$\Rightarrow 2x + CD = 3x$.

$\therefore CD = x$

Average speed

$\langle v \rangle = \frac{3x}{\frac{x}{v_1} + \frac{x}{v_2} + \frac{x}{v_3}} = \frac{3v_1v_2v_3}{v_2v_3 + v_1v_3 + v_1v_2}$

17. (d) Average velocity

$= \frac{V \sin\left(\frac{\theta}{2}\right)}{\left(\frac{\theta}{2}\right)} = \frac{2V \sin\left(\frac{\theta}{2}\right)}{\theta}$

$= \frac{2V \sin 60°}{\frac{2\pi}{3}} = 3 \sin 60° = 1.5\sqrt{3}$ m/s

18. (c) Average velocity $= \frac{\text{Total distance}}{\text{Total time}}$

$v = \frac{2x}{\frac{x}{v_1} + \frac{x}{v_2}} \Rightarrow \frac{1}{v_1} + \frac{1}{v_2} = \frac{2}{v}$

19. (d) Distance, $s = (2.5)t^2$

Speed $v = \frac{ds}{dt} = \frac{d}{dt}\{(2.5)t^2\} = 2 \times 2.5t$

$v = 5t$ At $t = 5$, $v = 25$ m/s.

20. (c) $x = 5t^2 - 4t + 5$

$\Rightarrow v = \frac{dx}{dt} = \frac{d}{dt}(5t^2 - 4t + 5) = 10t - 4$

At $t = 2$s and $v = 16$m/s

21. [18]

Let the distance AB is L.

Then, according to the question,

$t_1 = \frac{L}{3v_1}, t_2 = \frac{L}{3v_2}, t_3 = \frac{L}{3v_3}$

$V_{avg} = \frac{L}{t_1 + t_2 + t_3} = \frac{L}{\frac{L}{3v_1} + \frac{L}{3v_2} + \frac{L}{3v_3}}$

22. (d) $x = at + bt^2 - ct^3$

$v = \frac{dx}{dt} = a + 2bt - 3ct^2$

$a = \frac{dv}{dt} = 2b - 6ct = 0 \Rightarrow t = \frac{b}{3c}$

$v_{\left(at = \frac{b}{3c}\right)} = a + 2b\left(\frac{b}{3c}\right) - 3c\left(\frac{b}{3c}\right)^2$

$= a + \frac{b^2}{3c}$

23. (b) $v = b\sqrt{x}$

$\frac{dv}{dt} = \frac{b}{2\sqrt{x}} \frac{dx}{dt} \quad a = \frac{bv}{2\sqrt{x}}$

$a = \frac{b(b\sqrt{x})}{2\sqrt{x}} \Rightarrow \frac{dv}{dt} = a = \frac{b^2}{2}$

$v = \frac{b^2}{2}\tau \quad [\text{At } t = \tau]$

24. (Bonus)

$v^2 - u^2 = 2aS$

$\left(\frac{2u}{3}\right)^2 = u^2 + 2(-a)(4 \times 10^{-2})$

$\Rightarrow \frac{4u^2}{9} = u^2 - 2a(4 \times 10^{-2})$

$\Rightarrow -\frac{5u^2}{9} = -2a(4 \times 10^{-2}) \quad ...(1)$

$\Rightarrow 0 = \left(\frac{2u}{3}\right)^2 + 2(-a)(x)$

$\Rightarrow -\frac{4u^2}{9} = -2ax \quad ...(2)$

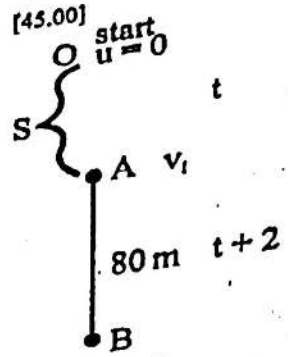
Dividing equation (1) by (2), we get

$\frac{5}{4} = \frac{4 \times 10^{-2}}{x} \Rightarrow x = \frac{16}{5} \times 10^{-2}$

$\Rightarrow x = 3.2 \times 10^{-3}$ m $= 32 \times 10^{-3}$ m

Note : Since no option is matching, Question should be bonus.

25. [45.00]



From A → B

$-80 = -v_1 t - \frac{1}{2} \times 10t^2$

$-80 = -2v_1 - \frac{1}{2} \times 10 \times 2^2$

$-80 = -2v_1 - 20 \Rightarrow v_1 = 30$ m/s

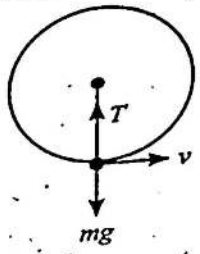
From O to A

$v^2 = u^2 + 2gS$

$30^2 = 0 + 2 \times (-10)(-S) \Rightarrow 900 = 20S$

$S = 45$ m

26. (b) Given that



$m = 900$ gm $= \frac{900}{1000}$ kg $= \frac{9}{10}$ kg

$r = 1$ m

$\omega = \frac{2\pi N}{60} = \frac{2\pi(10)}{60} = \frac{\pi}{3}$ rad/sec

The tension in the string,

$T - mg = mr\omega$

$T = mg + mr\omega^2$

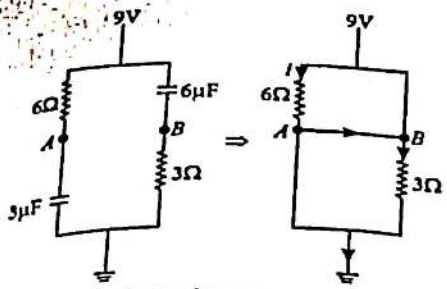
$= \frac{9}{10} \times 9.8 + \frac{9}{10} \times 1\left(\frac{\pi}{3}\right)^2 = 8.82 + 0.98$

$= 9.80$ N

27. [36]

At steady state, capacitor behaves as open circuit and current flows in circ as shown in the diagram.

@NAKE_CBSE_@RAJ_EDUNET



Equivalent resistance,

$R_{eq} = 9\,\Omega$

$i = \frac{9I'}{9W} = 1A$

$\Delta V'_{6\Omega} = 1 \times 6 = 6V$

$V'_A = 3V$

So, potential difference across 6μF is 6V.

The charge stored in 6(mu)F capacitor,

Hence, $Q = C\Delta V$

$= 6 \times 6 \times 10^{-6}\,C = 36\,\mu C$

28. [8] Given: $V = 4\sqrt{x}$

$$a = V\frac{dv}{dx}$$

$$= 4\sqrt{x} \times 4 \times \frac{1}{2}x^{-1/2} = 8 m/s^2$$

29. (b) $S_n = u + \frac{a}{2}(2n-1)$,

$$\Rightarrow 102.5 = u + \frac{a}{2}(2n-1) \;\&$$

$$115 = u + \frac{a}{2}(2n+3)$$

$$\Rightarrow 12.5 = 2a \Rightarrow a = 6.25 m/s^2$$

30. [40]

Given,

$$= u = 72 \text{ km/h} = 72 \times \frac{5}{18} = 20 \text{ m/s}$$

$v = u + at$

$0 = 20 + a \times 4$

$a = -5 m/s^2$

$v^2 - u^2 = 2as \Rightarrow 0^2 - 20^2 = 2(-5).s$

$s = 40$ m

31. [19]

By using the formula of distance travelled in n^{th} second

$$S_n = \frac{1}{2}a(2n-1) = \frac{19a}{2}$$

Similarly

$$S_{n-1} = \frac{1}{2}a(2n-3) = \frac{17a}{2}$$

$$\frac{S_{n-1}}{S_n} = \frac{17}{19} = 1 - \frac{2}{x} \Rightarrow x = 19$$

32. (a) $t_1 = \frac{u + \sqrt{u^2 + 2gh}}{g}$

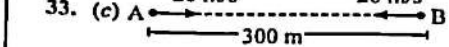
$$t_2 = \frac{-u + \sqrt{u^2 + 2gh}}{g}$$

$$t = \frac{\sqrt{2gh}}{g}$$

$$t_1 t_2 = \frac{\left(u^2 + 2gh\right) - u^2}{g^2} = \frac{2gh}{g^2} = t^2$$

$$\Rightarrow t = \sqrt{t_1 t_2}$$

33. (c)



Relative velocity, $|\vec{u}_{BA}| = 40$ m/s

Relative acceleration, $|\vec{a}_{BA}| = 4$ m/s

by using the equation, $(v^2 = u^2 + 2as)$

$0 = (40)^2 + 2(-4)(S)$

$S = 200$ m

Distance between them

$= 300 - 200 = 100$ m

34. [200]

$u = 20 m/s, S_1 = 500 m, v = 0$

Using third equation of motion

$0 = (20)^2 - 2a.500 \Rightarrow a = \frac{4}{10} m/s^2$

After brakes are applied

$u = 20 m/s, S_2 = 250 m, v = ?$

$v^2 = (20)^2 - 2a.250 = v = \sqrt{200}\, m/s$

$\therefore x = 200$

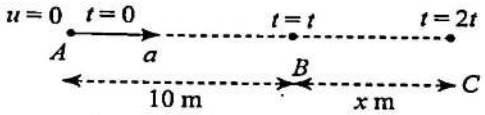
35. (d) Using law of motion's equation

$v = u + at$

$60 = 10 + 2t \Rightarrow 2t = 50$

$t = 25$ sec.

36. (c) According to question,



$$10 = \frac{1}{2}at^2 \quad ...(i)$$

$$10 + x = \frac{1}{2}a(2t)^2 \quad ...(ii)$$

On subtracting (i) from (ii), we get

$$\Rightarrow x = \frac{1}{2}a\left[(2t)^2 - t^2\right] = 3\left(\frac{1}{2}at^2\right) = 30 m$$

From (i) $\frac{1}{2}at^2 = 10$

Hence, option (c) is the correct answer.

37. [3] From Kinematic equation,

$v^2 = u^2 - 2aS \Rightarrow 0 = u^2 - 2aS$

$$S = \frac{u^2}{2a} \Rightarrow S \propto u^2$$

$$\therefore \frac{S_2}{S_1} = \left(\frac{u_2}{u_1}\right)^2 \Rightarrow S_2 = 27 \times \left(\frac{1}{3}\right)^2 = 3$$

38. [100]

It is given that $\frac{dv}{dx} = 5$

So, acceleration of particle is given by

$$a = v\frac{dv}{dx}$$

$a = 100 m/s^2 \Rightarrow (v = 20 m/s)$

39. (b) Let the length of train be l and its acceleration be a.

From kinematic equation.

$$\Rightarrow al = \frac{v^2 - u^2}{2}$$

Velocity when middle point crosses the post,

$$V_m = \sqrt{u^2 + 2a\frac{l}{2}} = \sqrt{u^2 + \frac{v^2 - u^2}{2}} = \sqrt{\frac{u^2 + v^2}{2}}$$

40. (c) $\sqrt{\frac{2\ell}{a_2}} - \sqrt{\frac{2\ell}{a_1}} = t \Rightarrow \frac{\sqrt{2\ell}}{t} = \frac{\sqrt{a_1 a_2}}{\sqrt{a_1} - \sqrt{a_2}}$

$$\sqrt{2a_1\ell} - \sqrt{2a_2\ell} = v$$

$$\Rightarrow \frac{\sqrt{2\ell}}{v} = \frac{1}{\sqrt{a_1} - \sqrt{a_2}}$$

$$\Rightarrow \frac{v}{t} = \sqrt{a_1 a_2} \Rightarrow v = \left(\sqrt{a_1 a_2}\right)t$$

41. [120]

Velocity of the ball just before reaching the ground,

$v_i = \sqrt{2gh_i} = 14 m/s$

Velocity of the ball just after the rebound,

$v_f = \sqrt{2gh_f} = 10 m/s$

$$\because \vec{a}_{Avg} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

$$\Rightarrow |\vec{a}_{avg}| = \left|\frac{\Delta\vec{v}}{\Delta t}\right| = 120 m/s^2$$

42. (b) Given, $u = 150$ m/s

From kinematic equations, $\vec{v} = \vec{u} + \vec{a}t$

$V = 150 - 10t$

At, $t = 3$ seconds

$V_1 = 150 - 30 = 120$

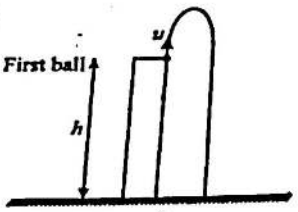
At, $t = 5$ seconds

$V_2 = 150 - 50 = 100$

$$\frac{120}{100} = \frac{x+1}{x} \Rightarrow x = 5$$

@FAKE_CBSE_KORAJ_EDUNET

43. [3]



For first ball, $s = ut + \frac{1}{2}at^2$

$-h = u \times 6 - \frac{1}{2} \times 10 \times 6 \times 6$

$h = 180 - 6u$ ...(i)

for second ball,

$h = u * 1.5 + \frac{1}{2} * 10 * 1.5 * 1.5$

$h = 1.5u + 11.25$ ...(ii)

From (i) and (ii)

$180 - 6u = 1.5u + 11.25$

$7.5u = 180 - 11.25 \Rightarrow u = 22.5$ m/s

For third ball

$\Rightarrow h = 0 * t + \frac{1}{2} * 10t^2$

$\Rightarrow 45 = 5t^2 \Rightarrow t = 3$ sec.

44. (b) For time of ascent,

$a = \frac{mg+10}{5} = \frac{5\times10+10}{5} = 12 m/sec^2$

From formula, $v = u + at$

$0 = u - 12t \Rightarrow t_A = \frac{u}{12}$ ...(i)

$h = ut + \frac{1}{2}at^2 = u \times \frac{u}{12} - \frac{1}{2} \times 12 \times \frac{u}{12} \times \frac{u}{12}$

$= \frac{u^2}{24}$ ...(ii)

For time of descent,

$a = \frac{50-10}{5} = 8 m/sec^2$

Using formula, $h = ut + \frac{1}{2}at^2$

$\Rightarrow \frac{u^2}{24} = 0 \times t + \frac{1}{2} \times 8t^2$

[From equation (ii)]

$\Rightarrow t_B = \frac{u}{\sqrt{96}}$ ...(iii)

On dividing equation (i) with equation (iii)

$\frac{t_A}{t_B} = \frac{\sqrt{2}}{\sqrt{3}}$

45. (a) At maximum height velocity, $v = 0$

$\therefore$ momentum $= mv = m \times 0 = 0$

46. [5] Let h be the height at which velocity becomes equal to magnitude of acceleration

$\therefore v = u + at$

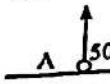
$10 = 0 + 10t \Rightarrow t = 1$ sec

$h = ut + \frac{1}{2}at^2$

$= 0 \times 1 + \frac{1}{2} \times 10 \times 1 \times 1 = 5$ m

47. [6] At $t = 2s$, distance covered by ball $= 80$ m

$\therefore h = 50t - \frac{1}{2} \times 10t^2 = 80m$



Now, velocity B with respect to A

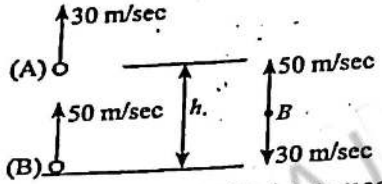
$V_{BA} = 50 - 30 = 20 m/sec$

Let time taken to collide be t.

$\therefore h = V_{BA}t$

$80 = 20t \Rightarrow t = 4$sec

Total time $= 4 + 2 = 6$ sec



48. (d) Let us suppose ball B travels (180 − 100) = 80 m in t second. Then ball A travels the same distance in $(t + 2)$ s. According to the question, for ball A.

$80 = \frac{1}{2}g \times (t+2)^2$

$\Rightarrow 80 = \frac{1}{2} \times 10 \times (t+2)^2 \Rightarrow t = 2$ sec

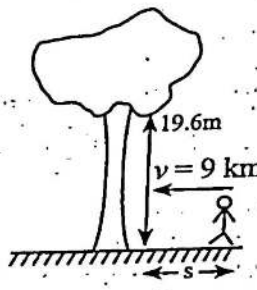
For ball B $80 = ut + \frac{1}{2}gt^2$

$80 = u \times 2 + \frac{1}{2} \times 10 \times (2)^2$

$\Rightarrow 60 = 2u \Rightarrow u = 30$ ms^{-1}

49. (a) The time taken by mango to fall from the tree is,

$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2\times19.6}{9.8}} = 2$sec



$\therefore$ The position of the cadet who receive the Mango will be,

$S = vt = \frac{9\times10^3}{3600} \times 2 = 5m$

50. [392] Applying, $s = ut + \frac{1}{2}at^2$

$h = 19.6 \times 2 + \frac{1}{2} \times 9.8 \times 4 = 58.8$m

Height above tower

$h' = \frac{u^2}{2g} = \frac{19.6\times19.6}{2\times9.8} = 19.6$

$\therefore H_{(\text{from ground})} = 19.6 + 58.8 = 78.4m$

As, $\frac{k}{5} = 78.4 \Rightarrow k = 392$

51. (b) At maximum height, velocity is zero so,

$0 = u^2 - 2gh$ or $u = \sqrt{2gh}$

As $s = ut + \frac{1}{2}at^2$ so, $\frac{h}{3} = \sqrt{2ght} - \frac{1}{2}gt^2$

$gt^2 - 2\sqrt{2ght} + \frac{2h}{3} = 0$ or

$t = \frac{2\sqrt{2gh} \pm \sqrt{8gh - \frac{8gh}{3}}}{2g}$

$\frac{t_1}{t_2} = \frac{2\sqrt{2gh} - \sqrt{8gh - \frac{8gh}{3}}}{2\sqrt{2gh} + \sqrt{8gh - \frac{8gh}{3}}} = \frac{\sqrt{3}-\sqrt{2}}{\sqrt{3}+\sqrt{2}}$

52. (d) Time to reach at max height, $t = \frac{u}{g}$

No. of balls thrown in 1 sec $= n$.

So, time taken by each ball $= \frac{1}{n}$ sec

i.e. $\frac{u}{g} = \frac{1}{n} \Rightarrow u = \frac{g}{n}$

So, $h_{max} = \frac{u^2}{2g} = \frac{g^2}{2gn^2} = \frac{g}{2n^2}$

53. (d) $\frac{h}{2} = \frac{1}{2}gt_1^2$ ...(i)

$h = \frac{1}{2}g(t_1 + t_2)^2$ ...(ii)

from (i) and (ii).

$\frac{1}{2}gt_1^2 = \frac{g}{4}(t_1 + t_2)^2 \Rightarrow t_2 = (\sqrt{2} - 1)t_1$

54. (d) Let time taken by the object to reach the ground be t.

Therefore, $s = ut + \frac{1}{2}at^2$

$-75 = 10t - \frac{1}{2}gt^2$

$5t^2 - 10t - 75 = 0$

$t = 5$ sec.

@FAKE_CBSE_GMAIL_EDUNET

Distance covered by balloon in 5 sec,
$h = 10 \times 5 = 50\text{m}$

Total height of balloon $= 75 + 50 = 125\text{m}$

55. (*b*) 5m below, velocity of first stone,
$v = \sqrt{2gs} = 10m/s$

$\therefore x + 20 = 10t + \frac{1}{2}gt^2$

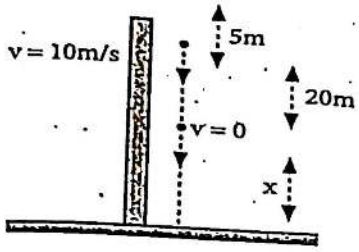
For second stone,

$x = \frac{1}{2}gt^2$

On solving these two equation, we get

$t = 2\text{sec}$ & $\therefore x = \frac{1}{2} \times 10 \times 4 = 20\text{m}$

$H = 20 + 5 = 45\text{m}$.



56. [50]

$h_1 = h_2$

$35t - \frac{1}{2}gt^2 = 35(t-3) - \frac{1}{2}g(t-3)^2$

$35 \times 3 = \frac{1}{2}g(t + t - 3) \times 3$

$105 = \frac{10}{2} \times 3 \times (2t - 3) \quad t = 5$

$h_1 = 35 \times 5 - \frac{1}{2} \times 10 \times 5^2 = 50\text{ m}$

57. (*a*) Time taken by first drop to reach the ground.

$t_1 = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 9.8}{9.8}} = \sqrt{2}s$

Time for which second drop has fallen,

$t_2 = t_1 - \frac{t_1}{2} = \sqrt{2} - \frac{1}{\sqrt{2}}s$

Height of the second drop

$= 9.8 - \frac{1}{2} \times 9.8 \times \left(\sqrt{2} - \frac{1}{\sqrt{2}}\right)^2 = 7.35\text{m}$

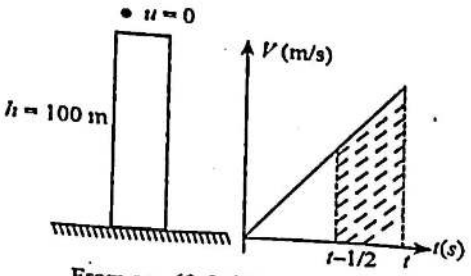
58. [8] Area of shaded trapezium

$= \frac{g\left[t - \frac{1}{2} + t\right]}{2} \times \frac{1}{2} = 19 \quad \ldots(i)$

Here, $h = 100$

Using, $S = ut + \frac{1}{2}at^2 = \frac{1}{2}gt^2 = 100 \ldots(ii)$

$\Rightarrow t = \sqrt{\frac{200}{g}}$



From eqn (*i*) & (*ii*)

$\frac{76}{g} = \frac{\left[4\sqrt{\frac{200}{g}} - 1\right]}{2}$

$g = 8\text{ m/s}^2$

59. (*d*) Displacement of the body $= 16 - 8 + 16 - 8 = 16m$

Distance travelled by the body $= \Sigma |\text{area}| = 48\ m$

$\Rightarrow \frac{\text{displacement}}{\text{Distance}} = \frac{1}{3}$

60. (*a*) $\frac{dx}{dt}$ = slope ≥ 0 always increasing $(A - \text{II})$

$\frac{dx}{dt} < 0$; and at $t \to \infty \frac{dx}{dt} \to 0$ $(B - \text{IV})$

$\frac{dx}{dt} > 0$ for first half $\frac{dx}{dt} < 0$ for second half. $(C - \text{III})$

$\frac{dx}{dt} = \text{constant}$ $(D - \text{I})$

61. (*c*) Area of velocity time graph gives displacement of body in given time.
Area under acceleration time graph gives change in velocity in the given time.

62. (*a*) As slope of $B >$ Slope of A
$\therefore$ Speed of $B >$ Speed of $A \Rightarrow t_B < t_A$

63. (*c*) Area under the graph from $t = 0$ to $t = 20$ sec

$A_1 = \frac{1}{2} \times 5 \times 10 + (5 \times 10) + \frac{1}{2} \times (10 + 20) \times 5 + \frac{1}{2} \times 5 \times 20 = 200m^2$

Area under the graph from $t = 20$ to $t = 25$ sec

$A_2 = \frac{1}{2} \times 5 \times (20) = 50m^2$

So distance covered $= A_1 + A_2$
$= (200 + 50)\text{m} = 250\text{ m}$
Displacement $= A_1 - A_2$
$= (200 - 50)\text{m}$
$= 150\text{ m}$

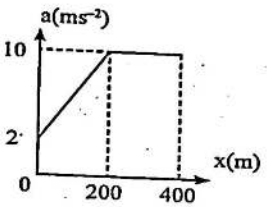
64. (*a*) Slope of $v - t$ graph is constant but negative for part AM. Slope of $v - t$ graph is constant but positive for part MB. Hence, option (*a*) is the correct slope of the acceleration- time graph.

65. (*d*) $\begin{cases} 10 + \frac{x}{5}, \text{if } 0 \leq x \leq 200m \\ 50, \text{if } 200m \leq x \leq 400m \end{cases}$

$\Rightarrow a = \frac{dv}{dt} = v\frac{dv}{dx}$

$= \begin{cases} \frac{1}{5}\left(10 + \frac{x}{5}\right), \text{if } 0 \leq x \leq 200m \\ 0 \qquad\qquad\quad , \text{if } 200m \leq x \leq 400m \end{cases}$

$\Rightarrow a = \begin{cases} \left(2 + \frac{x}{25}\right), \text{if } 0 \leq x \leq 200m \\ 0 \qquad\quad , \text{if } 200m \leq x \leq 400m \end{cases}$



66. (*b*) Acceleration (a) is constant
$\therefore v \propto t$ (Straight line graph)
And $x \propto t^2$ (parabolic graph)

67. (*a*) The slope of the given v versus x graph is $m = -\frac{v_0}{x_0}$ and intercept is $c = +v_0$.
Hence, varies with x as

$v = -\left(\frac{v_0}{x_0}\right)x + v_0 \quad \ldots(i)$

Using equation (*i*) in equation (*ii*), we get

$a = v\frac{dv}{dx} = \left(\frac{v_0}{x_0}\right)\left(-\frac{v_0}{x_0}x + v_0\right)$

$\Rightarrow a = \left(\frac{v_0}{x_0}\right)^2 x - \frac{v_0^2}{x_0}$

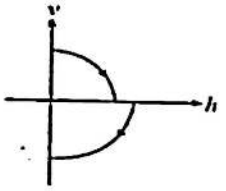
© FAKE_CBSE_X@RAJEDUNET

Thus the graph of a versus x is a straight line having a positive slope $= \left(\frac{v_0}{x_0}\right)^2$ and negative intercept $= -\frac{v_0^2}{x_0}$.

68. [1] As, $y = mx + c$
$v^2 = 2x + 20$
$v^2 = 2x + 20$
$\Rightarrow 2v\frac{dv}{dt} = 2v$
$\Rightarrow a = 1\ m/s^2$

69. [20]
Distance travelled = Area under the v-t graph
$\therefore \Delta S = \frac{1}{2}\times 5\times 8 = 20$

70. (b) At $H = h$, $v = 0$.



At $h = 0$, $v = \sqrt{2gh}$
Also $a = -g$, throughout this motion

71. (a) Distance $= |A_1| + |A_2|$
$= \frac{1}{2}\left(1+\frac{13}{3}\right)\times 4 + \frac{1}{2}\times\frac{5}{3}\times 2 = \frac{37}{3}$ m

72. (d) $r_{t=5}$ = area
$= \left(\frac{1}{2}\times 2\times 2 + 2\times 2 + 3\times 1\right)$m
$= (2 + 4 + 3) = 9$ m.

73. (c) We have, $u = 0$ and a = constant
At time t,
$v = 0 + at \Rightarrow v = at$
Also $x = 0(t) + \frac{1}{2}at^2 \Rightarrow x = \frac{1}{2}at^2$
Graph (a), (b) and (d) are correct.

74. (c) Given, $t = mx^2 + nx$
$\frac{dt}{dx} = 2mx + n \Rightarrow \frac{dx}{dt} = \frac{1}{2mx+n}$
$v = \frac{1}{2mx+n}$
Retardation of the motion.
$a = v\frac{dv}{dx} = v\frac{-2m}{(2mx+n)^2} = -2mv^3$

75. (b) $v = \alpha t + \beta t^2$
$\frac{ds}{dt} = \alpha t + \beta t^2 \Rightarrow ds = \left(\propto t + \beta t^2\right)dt$
Applying integration both side.
$\int_0^s ds = \int_1^2 \left(\alpha t + \beta t^2\right)dt$
$s = \left[\frac{\alpha t^2}{2} + \frac{\beta t^3}{3}\right]_1^2$
$s = \left[2\alpha + \frac{8\beta}{3}\right] - \left[\frac{\alpha}{2} + \frac{\beta}{3}\right]$
$= \frac{3\alpha}{2} + \frac{7\beta}{3}$

76. [3] We have given, the distance covered by particle varies with time t,
$x^2 = at^2 + 2bt + c$
$2xv = 2at + 2b$
$\Rightarrow xv = at + b$
differentiation again
$v^2 + ax = a$
$ax = a - \left(\frac{at+b}{x}\right)^2$
$a = \frac{a\left(at^2+2bt+c\right) - (at+b)^2}{x^3}$
$a = \frac{ac - b^2}{x^3}$; $a \propto x^{-3}$
Hence, value of n is 3.

77. (c) Given:
$V_A = 20$ m/s
$V_B = -30$ m/s
Velocity of B w.r.t. A
$V_{BA} = -50$ m/s
Velocity of ground w.r.t. B
$V_{GB} = 30$ m/s

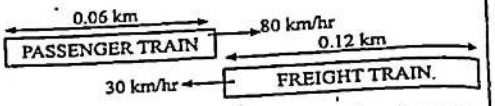
78. (c) $u_A = 108$ km/h
$= 30$ m/s
$u_B = 20$ m/s
$\because$ time$(t) = \frac{\text{distance}(s)}{\text{speed}(u)}$
$\therefore t_B - t_A = 35$
$\frac{s_B}{u_B} - \frac{s_A}{u_A} = 35$
$\frac{60\ell + 4\ell}{20} - \frac{61\ell}{30} = 35$
$\Rightarrow \ell = \frac{1050}{35}$
$\Rightarrow L = 60\ell = \frac{1050}{35}\times 60 = 1800$ m

79. (d) B $\xrightarrow{V_B}$ $\xleftarrow{V_A}$ A
Velocity of train A, $V_A = 90$ km/h $= -25$ m/s
$\because$ 1 km/h $= \frac{5}{18}$ m/s
Velocity of train B, $V_B = 54$ km/h $= 15$ m/s
Velocity of train B w.r.t. train A
$\rho = \rho_B - \rho_A = 15 - (-25)$
$= 40$ m/s
Time of crossing
$(t) = \frac{\text{length of train } (l)}{\text{relative velocity}(V)}$
$(8) = \frac{\ell}{40} \Rightarrow l = 8\times 40 = 320$ m

80. (d)
$X_p(t) = \alpha t + \beta t^2$
$V_p(t) = \frac{dX_p(t)}{dt} = \alpha + 2\beta t$ ... (i)
$X_Q(t) = ft - t^2$
$V_Q(t) = \frac{dX_Q(t)}{dt} = f - 2t$ ... (ii)
According to the question (i) = (ii)
$\alpha + 2\beta t = f - 2t \Rightarrow t(2\beta + 2) = f - \alpha$
$\therefore t = \frac{f-\alpha}{2(\beta+1)}$

81. (d) $V_A = 36$ km/hr $= 10$ m/s
$V_B = -72$ km/hr $= -20$ m/s
$V_{\text{wind}} = -1.8$ km/hr $= -0.5$ m/s
$V_{\text{man, }B} = V_{\text{man, }A} + V_{A,B}$
$= -0.5 + 10 - (-20) = 29.5$ m/s

82. (a)



Time taken if both moving in same direction
$t_1 = \frac{\text{distance}}{\text{speed}} = \frac{0.12+0.06}{80-30} = \frac{0.18}{50}$
Time taken if moving in opposite direction.
$t_2 = \frac{\text{distance}}{\text{speed}} = \frac{0.12+0.06}{80+30} = \frac{0.18}{110}$
$\frac{t_1}{t_2} = \frac{11}{5}$

@FAKE_CBSE_X @RAJEEDUNET

JEE-Advanced

1. *(c)* Let distance travel upto n sec is r_n, Then, from equation of motion,

$r_n = un + \frac{1}{2}an^2$

$r_{n-1} = u(n-1) + \frac{1}{2}a(n-1)^2$

Distance travelled in n^{th} second is,

$S_n = r_n - r_{n-1}$

$= un + \frac{1}{2}an^2 - \left(u(n-1) + \frac{1}{2}a(n-1)^2\right)$

$S_n = u + \frac{1}{2}an^2 - \frac{1}{2}a(n^2 - 2n + 1)$

$S_n = u + a\left(n - \frac{1}{2}\right)$

And here, block is starting from rest means $u = 0$

$S_n = a\left(n - \frac{1}{2}\right)$

Similarly, $s_{n+1} = a\left(n + 1 - \frac{1}{2}\right)$

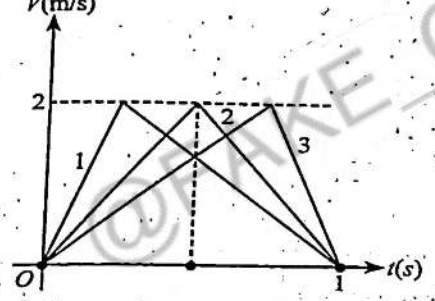
$\therefore \frac{S_n}{S_{n+1}} = \frac{a\left(n - \frac{1}{2}\right)}{a\left(n + 1 - \frac{1}{2}\right)} = \frac{2n-1}{2n+1}$.

2. *(c)* Since, the body is at rest at $x = 0$ and $x = 1$ Hence, α cannot be positive for all time in the interval $0 \le t \le 1$.

Hence, at first, the particle will accelerate and then retard.

Total time $t = 1$s

Total displacement, $s = 1$m



s = Area under $v - t$ graph

$s = \frac{1}{2}v_{max} \times t$

$\therefore$ Height or $v_{max} = \frac{2s}{t} = 2$ m/s is also fixed.

Area is fixed, when height and base is fixed.

So there can be 3 cases for $v_{max} = 2$ m/s

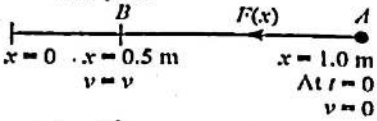
In case-I: Acceleration = Retardation $= 4$ m/s²

In case-II: Acceleration > 4 m/s² while Retardation < 4 m/s²

While in case-III: Acceleration < 4 m/s² and Retardation > 4 m/s²

Hence, $|\alpha| \ge 4$ at some point or points in its path.

3.



$F(x) = \frac{-k}{2x^2}$, k and x^2 both are positive.

Hence, $F(x)$ is always negative.

$a = \frac{F}{m} = \frac{-k}{2x^2m}$

$\int_0^v v dv = \int_1^x \left(\frac{-k}{2x^2m}\right) dx$

$\left(\frac{v^2}{2}\right)_0^v = \left(\frac{k}{2mx}\right)_1^x \Rightarrow \frac{v^2}{2} = \frac{k}{2m}\left(\frac{1}{x} - \frac{1}{1}\right)$

$v = -\sqrt{\frac{k}{m}\left(\frac{1}{x} - 1\right)}$ ....(i)

'–' sign since it moves

Put $x = 0.5$ backward because of force

$v = -\sqrt{\frac{k}{m}\left(\frac{1}{0.5} - 1\right)} \Rightarrow V = -\sqrt{\frac{k}{m}}$

Substituting the values,

$V = \pm\sqrt{\frac{10^{-2}}{10^{-2}}} = \pm 1$ m/s

Therefore, velocity of particle at $x = 0.5$ m is $v = -1.0$ m/s

Velocity is in negative, because it is going in backward direction.

(b) From above we get, $V = -\sqrt{\frac{k}{m}}$

$\frac{dx}{dt} = -\sqrt{\frac{k}{m}\left(\frac{1}{x} - 1\right)}$

$\left(\sqrt{\frac{m}{k}\left(\frac{x}{1-x}\right)}\right) dx = -dt$

$\int_{\pi/2}^{\pi/6} \left(\sqrt{\frac{10^{-2}}{10^{-2}}\left(\frac{x}{1-x}\right)}\right) dx = \int_0^t -dt$

Put $x = \sin^2\theta$

$dx = 2\sin\theta\cos\theta\, d\theta$ range of integration also changed

$\int_{\pi/2}^{\pi/6} \left(\sqrt{\left(\frac{\sin^2\theta}{1-\sin^2\theta}\right)}\right) 2\sin\theta\cos\theta d\theta$

$= \int_0^t -dt$

$\int_{\pi/2}^{\pi/6} \left(\frac{\sin\theta}{\cos\theta}\right) 2\sin\theta\cos\theta d\theta = \int_0^t -dt$

$\int_{\pi/2}^{\pi/6} 2\sin^2\theta d\theta = \int_0^t -dt$

$\cos 2\theta = 1 - 2\sin^2\theta \Rightarrow 2\sin^2\theta = 1 - \cos^2\theta$

$\int_{\pi/2}^{\pi/6} (1 - \cos 2\theta) d\theta = \int_0^t -dt$

$\left[\theta - \frac{\sin 2\theta}{2}\right]_{\Pi/2}^{\Pi/6} = -t$

$\left(\frac{\Pi}{6} - \frac{\sin 2\left(\frac{\Pi}{6}\right)}{4}\right) - \left(\frac{\Pi}{2} - \frac{\sin 2\left(\frac{\Pi}{2}\right)}{2}\right) = -t$

$-\frac{\Pi}{3} - \frac{\sqrt{3}}{4} = -t$

$t = \left(\frac{\Pi}{3} + \frac{\sqrt{3}}{4}\right)$ sec

4. *(a)* From the given graph, the $v - x$ equation can be written as

$v = \left(-\frac{v_0}{x_0}\right)x + v_0$

$a = \frac{dv}{dt} = \left(-\frac{v_0}{x_0}\right)\frac{dx}{dt} = \left(-\frac{v_0}{x_0}\right)v$

Substituting v we get,

$a = \left(-\frac{v_0}{x_0}\right)\left[\left(-\frac{v_0}{x_0}\right)x + v_0\right]$

$\Rightarrow a = \left(\frac{v_0}{x_0}\right)^2 x - \frac{v_0^2}{x_0}$

Hence, we get $a - x$ graph as straight line with positive slope and negative intercept.

5. [8] Let S_1 be the distance covered by ball 1 before collision and S_2 by ball 2.

Given, $u_1 = 0.3$ m/s $u_2 = -0.2$ m/s

And there is pseudo acceleration on balls

$S_1 = u_1 t + \frac{1}{2}at^2 = 0.3t - \frac{1}{2}(2)t^2$

$S_2 = u_2 t + \frac{1}{2}at^2 = 0.2t + \frac{1}{2}(2)t^2$

From the given information $S_1 + S_2 = 4$

$0.3t - \frac{1}{2}(2)t^2 + 0.2t + \frac{1}{2}(2)t^2 = 4$

$0.3t + 0.2t = 4 \Rightarrow 0.5t = 4$

$t = \frac{4}{0.5} = 8s$

@MAKE_CRACK @RAJ_EDUNET

Motion in a Plane

Scan for Sol

JEE-Main

Motion in a Plane with Constant Acceleration

1. Position of an ant (S in metres) moving in Y-Z plane is given by $S = 2t^2\hat{j} + 5\hat{k}$ (where t is in second). The magnitude and direction of velocity of the ant at $t = 1$ s will be: **[27 Jan, 2024 (Shift-I)]**
   (a) 16 m/s in y-direction (b) 4 m/s in x-direction
   (c) 9 m/s in z-direction (d) 4 m/s in y-direction

2. A particle starts from origin at $t = 0$ with a velocity $5\hat{i}$ m/s and moves in x-y plane under action of a force which produces a constant acceleration of $(3\hat{i} + 2\hat{j})$m/s². If the x-coordinate of the particle at that instant is 84 m, then the speed of the particle at this time is $\sqrt{\alpha}$ m/s. The value of α is _____. **[27 Jan, 2024 (Shift-I)]**

3. The co-ordinates of a particle moving in x-y plane are given by: $x = 2 + 4t$, $y = 3t + 8t^2$.
   The motion of the particle is: **[04 April, 2024 (Shift-I)]**
   (a) non-uniformly accelerated.
   (b) uniformly accelerated having motion along a straight line.
   (c) uniform motion along a straight line.
   (d) uniformly accelerated having motion along a parabolic path.

4. A force on an object of mass 100 g is $(10\hat{i} + 5\hat{j})$N. The position of that object at $t = 2$s is $(a\hat{i} + b\hat{j})$m after starting from rest. The value of a/b will be _____. **[25 June, 2022 (Shift-I)]**

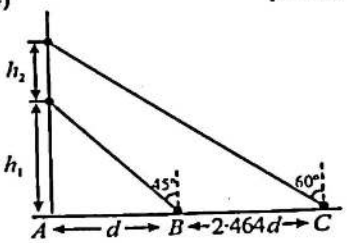
5. At time $t = 0$ a particle starts travelling from a height $7\hat{z}$ cm in a plane keeping z coordinate constant. At any instant of time it's position along the $\hat{x}$ and $\hat{y}$ directions are defined as $3t$ and $5t^3$ respectively. At $t = 1s$ acceleration of the particle will be **[28 July, 2022 (Shift-II)]**
   (a) $-30\hat{y}$ (b) $30\hat{y}$ (c) $3\hat{x} + 15\hat{y}$ (d) $3\hat{x} + 15\hat{y} + 7\hat{z}$

6. A particle is moving along the x-axis with its coordinate with time 't' given by $x(t) = 10 + 8t - 3t^2$. Another particle is moving along the y-axis with its coordinate as a function of time given by $y(t) = 5 - 8t^3$. At $t = 1s$, the speed of the second particle as measured in the frame of the first particle is given as $\sqrt{v}$. Then v(in m/s) is **[8 Jan, 2020 (Shift-I)]**

7. A particle starts from the origin at $t = 0$ with an initial velocity of $3.0\hat{i}$ m/s and moves in the x-y plane with a constant acceleration $(6.0\hat{i} + 4.0\hat{j})$ m/s². The x-coordinate of the particle at the instant when its y-coordinate is 32 m is D meters. The value of D is **[9 Jan, 2020 (Shift-II)]**
   (a) 50 (b) 40 (c) 32 (d) 60

8. Starting from the origin at time $t = 0$, with initial velocity $5\hat{j}$ m/s, a particle moves in the x-y plane with a constant acceleration of $(10\hat{i} + 4\hat{j})$ m/s². At time t, its coordinates are (20 m, y_0 m). The values of t and y_0 are, respectively **[4 Sep, 2020 (Shift-I)]**
   (a) 4 s and 52 m (b) 2 s and 24 m
   (c) 5 s and 25 m (d) 2 s and 18 m

9. A balloon is moving up in air vertically above a point A on the ground. When it is at a height h_1, a girl standing at a distance d (point B) from A (see figure) sees it at an angle 45° with respect to the vertical. When the balloon climbs up a further height h_2, it is seen at an angle 60° with respect to the vertical if the girl moves further by a distance 2.464 d (point C). Then the height h_2 is (given tan 30° = 0.5774) **[5 Sep, 2020 (Shift-I)]**



   (a) d (b) 0.732 d (c) 1.464 d (d) 0.464 d

10. A particle is moving with a velocity $\vec{v} = K(y\hat{i} + x\hat{j})$, where K is a constant. The general equation for its path is: **[9 Jan, 2019 (Shift-I)]**
    (a) $y = x^2$ + constant (b) $y^2 = x$ + constant
    (c) $y^2 = x^2$ + constant (d) xy = constant

11. A particle moves from the point $(2.0\hat{i} + 4.0\hat{j})$m, at $t = 0$ with an initial velocity $(5.0\hat{i} + 4.0\hat{j})$ms^{-1}. It is acted upon by a constant force which produces a constant acceleration $(4.0\hat{i} + 4.0\hat{j})$ms^{-2}. What is the distance of the particle from the origin at time 2s? **[11 Jan, 2019 (Shift-II)]**
    (a) 15 m (b) $20\sqrt{2}$ m (c) 5 m (d) $10\sqrt{2}$ m

@FAST_CBSE_X@QR_EDUNET

12. The position co-ordinates of a particle moving in a 3-D coordinates system is given by
$x = a\cos\omega t$
$y = a\sin\omega t$
and $z = a\omega t$
The speed of the particle is: [9 Jan, 2019 (Shift-II)]
(a) $\sqrt{2}a\omega$ (b) $a\omega$ (c) $\sqrt{3}a\omega$ (d) $2a\omega$

13. The position vector of a particle changes with time according to the relation $\vec{r}(t) = 15t^2\hat{i} + (4 - 20t^2)\hat{j}$. What is the magnitude of the acceleration at $t = 1$? [9 April, 2019 (Shift-II)]
(a) 40 m/s². (b) 100 m/s² (c) 25 m/s² (d) 50 m/s²

"Projectile Motion: Ground to Ground Projection"

14. Projectiles A and B are thrown at angles of 45° and 60° with vertical respectively from top of a 400 m high tower. If their ranges and times of flight are same, the ratio of their speeds of projection v_A : v_B is: [30 Jan, 2024 (Shift-II)]
(a) $1:\sqrt{3}$ (b) $\sqrt{2}:1$ (c) $1:2$ (d) $1:\sqrt{2}$

15. A particle moving in a circle of radius R with uniform speed takes time T to complete one revolution. If this particle is projected with the same speed at an angle θ to the horizontal, the maximum height attained by it is equal to $4R$. The angle of projection θ is then given by: [1 Feb, 2024 (Shift-I)]
(a) $\sin^{-1}\left[\frac{2gT^2}{\pi^2 R}\right]^{\frac{1}{2}}$ (b) $\sin^{-1}\left[\frac{\pi^2 R}{2gT^2}\right]^{\frac{1}{2}}$
(c) $\cos^{-1}\left[\frac{2gT^2}{\pi^2 R}\right]^{\frac{1}{2}}$ (d) $\cos^{-1}\left[\frac{\pi R}{2gT^2}\right]^{\frac{1}{2}}$

16. The maximum height reached by a projectile is 64 m. If the initial velocity is halved, the new maximum height of the projectile is _____ m. [05 April, 2024 (Shift-II)]

17. The angle of projection for a projectile to have same horizontal range and maximum height is: [08 April, 2024 (Shift-II)]
(a) $\tan^{-1}(2)$ (b) $\tan^{-1}(4)$ (c) $\tan^{-1}\left(\frac{1}{4}\right)$ (d) $\tan^{-1}\left(\frac{1}{2}\right)$

18. The range of the projectile projected at an angle of 15° with horizontal is 50 m. If the projectile is projected with same velocity at an angle of 45° with horizontal, then its range will be: [10 April, 2023 (Shift-I)]
(a) 50 m (b) $50\sqrt{2}$ m (c) 100 m (d) $100\sqrt{2}$ m

19. The initial speed of a projectile fired from ground is u. At the highest point during its motion, the speed of projectile is $\frac{\sqrt{3}}{2}u$. The time of flight of the projectile is: [31 Jan, 2023 (Shift-I)]
(a) $\frac{u}{2g}$ (b) $\frac{u}{g}$ (c) $\frac{2u}{g}$ (d) $\frac{\sqrt{3}u}{g}$

20. The trajectory of projectile, projected from the ground is given by $y = x - \frac{x^2}{20}$. Where x and y are measured in meter. The maximum height attained by the projectile will be. [8 April, 2023 (Shift-II)]
(a) 5 m (b) $10\sqrt{2}$ m (c) 200 m (d) 10 m

21. For a body projected at an angle with the horizontal from the ground, choose the correct statement. [1 Feb, 2023 (Shift-II)]
(a) Gravitational potential energy is maximum at the highest point.
(b) The horizontal component of velocity is zero at highest point.
(c) The vertical component of momentum is maximum at the highest point.
(d) The kinetic energy (K.E.) is zero at the highest point of projectile motion.

22. Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R.
Assertion A: When a body is projected at an angle 45°, it's range is maximum.
Reason R: For maximum range, the value of sin2θ should be equal to one.
In the light of the above statements, choose the correct answer from the options given below: [6 April, 2023 (Shift-I)]
(a) Both A and R are correct but R is NOT the correct explanation of A
(b) Both A and R are correct R is the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

23. A projectile is projected at 30° from horizontal with initial velocity 40 ms^{-1}. The velocity of the projectile at $t = 2$ s from the start will be: (Given $g = 10$ m/s^2) [11 April, 2023 (Shift-II)]
(a) $20\sqrt{3}$ ms^{-1} (b) $40\sqrt{3}$ ms^{-1}
(c) 20 ms^{-1} (d) Zero

24. Two objects are projected with the same velocity 'u' however at different angles α and β with the horizontal. If $\alpha + \beta = 90°$, the ratio of horizontal range of the first object to the 2nd object will be: [25 Jan, 2023 (Shift-II)]
(a) 4 : 1 (b) 2 : 1 (c) 1 : 2 (d) 1 : 1

25. Two projectiles are projected at 30° and 60° with the horizontal with the same speed. The ratio of the maximum height attained by the two projectiles respectively is: [10 April, 2023 (Shift-II)]
(a) $2:\sqrt{3}$ (b) $\sqrt{3}:1$ (c) $1:3$ (d) $1:\sqrt{3}$

26. The maximum vertical height to which a man can throw a ball is 136 m. The maximum horizontal distance upto which he can throw the same ball is [24 Jan, 2023 (Shift-I)]
(a) 192 m (b) 136 m (c) 272 m (d) 68 m

27. A projectile fired at 30° to the ground is observed to be at same height at time 3s and 5s after projection, during its flight. The speed of projection of the projectile is _____ ms^{-1}
(Given g = 10 ms^{-2}) [11 April, 2023 (Shift-I)]

28. Two bodies are projected from ground with same speeds 40ms^{-1} at two different angles with respect to horizontal. The bodies were found to have same range. If one of the body was projected at an angle of 60°, with horizontal then sum of the maximum heights, attained by the two projectiles, is _____ m. (Given g = 10ms^{-2}) [31 Jan, 2023 (Shift-II)]

@TAKE CARE X @NEET DUNET

29. A stone is projected at angle 30° to the horizontal. The ratio of kinetic energy of the stone at point of projection to its kinetic energy at the highest point of flight will be [29 Jan, 2023 (Shift-I)]
(a) 1 : 2 (b) 1 : 4 (c) 4 : 1 (d) 4 : 3

30. Two projectiles A and B are thrown with initial velocities of 40 m/s and 60 m/s at angles 30° and 60° with the horizontal respectively. The ratio of their ranges respectively is ($g = 10$ m/s^2) [8 April, 2023 (Shift-I)]
(a) $\sqrt{3}:2$ (b) $2:\sqrt{3}$ (c) 1 : 1 (d) 4 : 9

31. Given below are two statements. One is labelled as Assertion A and the other is labelled as Reason R.
Assertion A: Two identical balls A and B thrown with same velocity 'u' at two different angles with horizontal attained the same range R. If A and B reached the maximum height h_1 and h_2 respectively, then $R = 4\sqrt{h_1 h_2}$
Reason R: Product of said heights.
$$h_1 h_2 = \left(\frac{u^2 \sin^2\theta}{2g}\right)\cdot\left(\frac{u^2\cos^2\theta}{2g}\right)$$
Choose the correct answer: [25 June, 2022 (Shift-II)]
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is NOT the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

32. A projectile is launched at an angle 'α' with the horizontal with a velocity 20 ms^{-1}. After 10 s, it inclination with horizontal is 'β'. The value of tanβ will be: ($g = 10$ ms^{-2}). [27 June, 2022 (Shift-I)]
(a) tanα + 5secα (b) tanα − 5secα
(c) 2 tanα − 5secα (d) 2tanα + 5secα

33. Two projectiles are thrown with same initial velocity making an angle of 45° and 30° with the horizontal respectively. The ratio of their respective ranges will be: [26 July, 2022 (Shift-II)]
(a) $1:\sqrt{2}$ (b) $\sqrt{2}:1$ (c) $2:\sqrt{3}$ (d) $\sqrt{3}:2$

34. A body of mass 10 kg is projected at an angle of 45° with the horizontal. The trajectory of the body is observed to pass through a point (20, 10). If T is the time of flight, then its momentum vector, at time $t = \frac{T}{\sqrt{2}}$ is_____
[Take $g = 10$ m/s^2] [27 July, 2022 (Shift-II)]
(a) $100\hat{i} + (100\sqrt{2} - 200)\hat{j}$ (b) $100\sqrt{2}\,\hat{i} + (100 - 200\sqrt{2})\hat{j}$
(c) $100\hat{i} + (100 - 200\sqrt{2})\hat{j}$ (d) $100\sqrt{2}\,\hat{i} + (100\sqrt{2} - 200)\hat{j}$

35. A projectile is projected with velocity of 25 m/s at an angle θ with the horizontal. After t seconds its inclination with horizontal becomes zero. If R represents horizontal range of the projectile, the value of θ will be: [24 June, 2022 (Shift-I)]
(a) $\frac{1}{2}\sin^{-1}\left(\frac{5t^2}{4R}\right)$ (b) $\frac{1}{2}\sin^{-1}\left(\frac{4R}{5t^2}\right)$
(c) $\tan^{-1}\left(\frac{4t^2}{5R}\right)$ (d) $\cot^{-1}\left(\frac{R}{20t^2}\right)$

36. A ball is projected from the ground with a speed 15 ms^{-1} at an angle θ with horizontal so that its range and maximum height are equal. Then 'tanθ' will be equal to: [25 July, 2022 (Shift-II)]
(a) 1/4 (b) 1/2 (c) 2 (d) 4

37. A person can throw a ball upto a maximum range of 100 m. How high above the ground he can throw the same ball? [29 June, 2022 (Shift-II)]
(a) 25 m (b) 50 m (c) 100 m (d) 200 m

38. A body is projected from the ground at an angle of 45° with horizontal. Its velocity after 2s is 20 ms^{-1}. The maximum height reached by the body during its motion is _____m. (use $g = 10$ms^{-2}) [24 June, 2022 (Shift-II)]

39. If the initial velocity in horizontal direction of a projectile is unit vector $\hat{i}$ and the equation of trajectory is $y = 5x(1 - x)$. The y component vector of the initial velocity is _____$\hat{j}$. [26 July, 2022 (Shift-I)]
(Take $g = 10$ m/s^2)

40. An object is projected in the air with initial velocity u at an angle θ. The projectile motion is such that the horizontal range R, is maximum. Another object is projected in the air with a horizontal range half of the range of first object. The initial velocity remains same in both the case. The value of the angle of projection, at which the second object is projected, will be _____ degree. [29 July, 2022 (Shift-I)]

41. A ball is projected with kinetic energy E, at an angle of 60° to the horizontal. The kinetic energy of this ball at the highest point of its flight will become: [29 July, 2022 (Shift-I)]
(a) Zero (b) $\frac{E}{2}$ (c) $\frac{E}{4}$ (d) E

42. Two projectile thrown at 30° and 45° with the horizontal respectively, reach the maximum height in same time. The ratio of their initial velocities is [26 July, 2022 (Shift-I)]
(a) $1:\sqrt{2}$ (b) 2 : 1 (c) $\sqrt{2}:1$ (d) 1 : 2

43. A ball of mass m is thrown vertically upward. Another ball of mass 2 m is thrown an angle θ with the vertical. Both the balls stay in air for the same period of time. The ratio of the heights attained by the two balls respectively is $\frac{1}{x}$. The value of x is _____. [27 July, 2022 (Shift-I)]

44. A body is projected at $t = 0$ with a velocity 10 ms^{-1} at an angle of 60° with the horizontal. The radius of curvature of its trajectory at $t = 1$ s is R. Neglecting air resistance and taking acceleration due to gravity $g = 10$ ms^{-2} the radius of R is: [11 Jan, 2019 (Shift-I)]
(a) 10.3 m (b) 2.8 m (c) 2.5 m (d) 5.1 m

45. Two guns A and B can fire bullets at speed 1 km/s and 2 km/s respectively. From a point on a horizontal ground, they are fired in all possible directions. The ratio of maximum areas covered by the bullets fired by the two guns, on the ground is: [10 Jan, 2019 (Shift-I)]
(a) 1 : 16 (b) 1 : 2 (c) 1 : 4 (d) 1 : 8

46. A shell is fired from a fixed artillery gun with an initial speed u such that it hits the target on the ground at a distance R from it. If t_1 and t_2 are the values of the time taken by it to hit the target in two possible ways, the product $t_1 t_2$ is: [12 April, 2019 (Shift-I)]
(a) R/g (b) $R/4g$ (c) $2R/g$ (d) $R/2g$

47. Two particles are projected from the same point with the same speed u such that they have the same range R, but different maximum heights, h_1 and h_2. Which of the following is correct? [12 April, 2019 (Shift-II)]
(a) $R^2 = 2h_1 h_2$ (b) $R^2 = 16h_1 h_2$ (c) $R^2 = 4h_1 h_2$ (d) $R^2 = h_1 h_2$

@FAKE_OBJECT @JEEDUNIA

48. The trajectory of a projectile near the surface of the earth is given as $y = 2x - 9x^2$. If it were launched at an angle θ_0 with speed v_0 then ($g = 10\ ms^{-2}$) [12 April, 2019 (Shift-I)]

(a) $\theta_0 = \cos^{-1}\left(\frac{2}{\sqrt{5}}\right)$ and $v_0 = \frac{3}{5} ms^{-1}$

(b) $\theta_0 = \sin^{-1}\left(\frac{1}{\sqrt{5}}\right)$ and $v_0 = \frac{5}{3} ms^{-1}$

(c) $\theta_0 = \sin^{-1}\left(\frac{2}{\sqrt{5}}\right)$ and $v_0 = \frac{3}{5} ms^{-1}$

(d) $\theta_0 = \cos^{-1}\left(\frac{1}{\sqrt{5}}\right)$ and $v_0 = \frac{5}{3} ms^{-1}$

49. A ball is thrown from ground at an angle θ with horizontal and with an initial speed u_0. For the resulting projectile motion, the magnitude of average velocity of the ball up to the point when it hits the ground for the first time is V_1

After hitting the ground, ball rebounds at the same angle θ but with a reduced speed of u_0/α. Its motion continues for a long time as shown in figure. If the magnitude of average velocity of the ball for entire duration of motion is 0.8 V_1, the value of α is_____

[JEE Adv, 2019]

Horizontal Projectile

50. A ball rolls off the top of a stairway with horizontal velocity u. The steps are 0.1 m high and 0.1 m wide. The minimum velocity u with which that ball just hits the step 5 of the stairway will be $\sqrt{x}$ ms^{-1} where $x =$ _____ [use $g = 10\ m/s^2$].[29 Jan, 2024 (Shift-I)]

51. A body of mass M thrown horizontally with velocity v from the top of the tower of height H touches the ground at a distance of 100m from the foot of the tower. A body of mass 2 M thrown at a velocity $v/2$ from the top of the tower of height $4H$ will touch the ground at a distance of ..... m. [08 April, 2024 (Shift-II)]

52. A child stands on the edge of the cliff 10 m above the ground and throws a stone horizontally with an initial speed of 5 ms^{-1}. Neglecting the air resistance, the speed with which the stone hits the ground will be ms^{-1} (given, $g = 10\ ms^{-1}$).

[1 Feb, 2023 (Shift-I)]

(a) 20 (b) 15 (c) 30 (d) 25

53. A helicopter rises from rest on the ground vertically upwards with a constant acceleration g. A food packet is dropped from the helicopter when it is at a height h. The time taken by the packet to reach the ground is close to [g is the acceleration due to gravity]

[5 Sep, 2020 (Shift-I)]

(a) $t = 3.4\sqrt{\left(\frac{h}{g}\right)}$ (b) $t = 1.8\sqrt{\frac{h}{g}}$

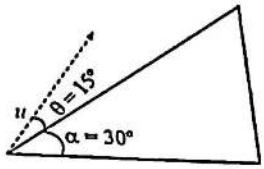
(c) $t = \sqrt{\frac{2h}{3g}}$ (d) $t = \frac{2}{3}\sqrt{\left(\frac{h}{g}\right)}$

Projectile Motion on an Inclined Plane

54. A plane is inclined at an angle $\alpha = 30°$ with a respect to the horizontal. A particle is projected with a speed $u = 2\ ms^{-1}$ from the base of the plane, making an angle $\theta = 15°$ with respect to the plane as shown in the figure.

The distance from the base, at which the particle hits the plane is close to: [10 April, 2019 (Shift-II)]

(Take $g = 10\ ms^{-2}$)



(a) 14 cm (b) 20 cm (c) 18 cm (d) 26 cm

Two Dimensional Relative Motion

55. The speed of a swimmer is 4 km hr^{-1} in still water. If the swimmer makes his strokes normal to the flow of river of width 1 km, he reaches a point 750 m down the stream on the opposite bank. The speed of the river water is _____ km hr^{-1}.

[31 Jan, 2023 (Shift-I)]

56. A fighter jet is flying horizontally at a certain with a speed of 200 ms^{-1}.When it passes directly overhead an anti-aircraft gun, a bullet is fired from the gun, at an angle θ with the horizontal, to hit the jet. If the bullet speed is 400 m/s, the value of θ will be _____.

[26 June, 2022 (Shift-I)]

57. A girl standing on road holds her umbrella at 45° with the vertical to keep the rain away. If she starts running without umbrella with a speed of $15\sqrt{2}\ kmh^{-2}$, the rain drops hit her head vertically. The speed of rain drops with respect to the moving girl is:

[27 June, 2022 (Shift-I)]

(a) 30 kmh–1 (b) $\frac{25}{\sqrt{2}} kmh^{-1}$

(c) $\frac{30}{\sqrt{2}} kmh^{-1}$ (d) 25 kmh–1

58. When a car is at rest, its driver sees rain drops falling on it vertically. When driving the car with speed v, he sees that rain drops are coming at an angle 60° from the horizontal. On further increasing the speed of the car to $(1 + \beta)v$, this angle changes to 45°. The value of β is close to [6 Sep, 2022 (Shift-II)]

(a) 0.37 (b) 0.41 (c) 0.73 (d) 0.50

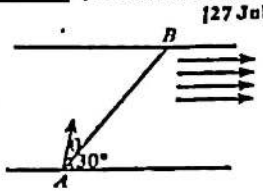
59. A butterfly is flying with a velocity $4\sqrt{2}$ m/s in North – East direction. Wind is slowly blowing at 1 m/s from North to South. The resultant displacement of the butterfly in 3 seconds is:

[20 July, 2021 (Shift-I)]

(a) 15m (b) 20m (c) 3 m (d) $12\sqrt{2}$m

@FAKE_CRACK@FREEDUNET

60. A swimmer wants to cross a river from point A to point B. Line AB makes an angle of 30° with the flow of river. Magnitude of velocity of the swimmer is same as that of the river. The angle θ with the line AB should be _____°, so that the swimmer reaches point B.
[27 July, 2021 (Shift-II)]



61. A swimmer can swim with velocity of 12 km/ h in still water. Water flowing in a river has velocity 6 km/ h. The direction with respect to the direction of flow of river water he should swim in order to reach the point on the other bank just opposite to his starting point is _____°. (Round off to the Nearest Integer)
(Find the angle in degrees) [16 March, 2021 (Shift-II)]

62. A person is swimming with a speed of 10 m/s at an angle of 120° with the flow and reaches to a point directly opposite on the other side of the river. The speed of the flow is 'x' m/s. The value of 'x' to the nearest integer is _____. [18 March, 2021 (Shift-I)]

63. Ship A is sailing towards north-east with velocity $\vec{v}=30\hat{i}+50\hat{j}$ km/hr where $\hat{i}$ points east and $\hat{j}$, north. Ship B is at a distance of 80 km east and 150 km north of Ship A and is sailing towards west at 10 km/hr. A will be at minimum distance from B in:
[8 April, 2019 (Shift-I)]
(a) 4.2 hrs. (b) 2.2 hrs. (c) 3.2 hrs. (d) 2.6 hrs.

64. The stream of a river is flowing with a speed of 2km/h. A swimmer can swim at a speed of 4km/h. What should be the direction of the swimmer with respect to the flow of the river to cross the river straight? [9 April, 2019 (Shift-I)]
(a) 60° (b) 150° (c) 90° (d) 120°

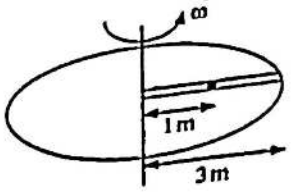
Uniform Circular Motion

65. If the radius of curvature of the path of two particles of same mass are in the ratio 3:4, then in order to have constant centripetal force, their velocities will be in the ratio of: [29 Jan, 2024 (Shift-I)]
(a) $\sqrt{3}:2$ (b) $1:\sqrt{3}$ (c) $\sqrt{3}:1$ (d) $2:\sqrt{3}$

66. A particle is moving in a circle of radius 50 cm in such a way that at any instant the normal and tangential components of its acceleration are equal. If its speed at $t=0$ is 4 m/s, the time taken to complete the first revolution will be $\frac{1}{\alpha}[1-e^{-2\pi}]s$, where $\alpha=$_____. is
[29 Jan, 2024 (Shift-II)]

67. A clock has 75 cm, 60 cm long second hand and minute hand respectively. In 30 minutes duration the tip of second hand will travel x distance more than the tip of minute hand. The value of x in meter is nearly (Take $\pi=3.14$): [08 April, 2024 (Shift-I)]
(a) 139.4 (b) 140.5 (c) 220.0 (d) 118.9

68. A circular table is rotating with an angular velocity of ω rad/s about its axis (see figure). There is a smooth groove along a radial direction on the table. A steel ball is gently placed at a distance of 1 m on the groove. All the surface are smooth. If the radius of the table is 3 m, the radial velocity of the ball w.r.t. the table at the time ball leaves the table is $x\sqrt{2}\omega$ m/s, where the value of x is.....
[08 April, 2024 (Shift-II)]



69. An object moves at a constant speed along a circular path in a horizontal plane with centre at the origin. When the object is at $x=+2m$, its velocity is $-4\hat{j}m/s$. The object's velocity (v) and acceleration (a) at $x=-2m$ will be [29 Jan, 2023 (Shift-II)]
(a) $v=4\hat{i}m/s, a=8\hat{j}m/s^2$ (b) $v=4\hat{j}m/s, a=8\hat{i}m/s^2$
(c) $v=-4\hat{j}m/s, a=8\hat{i}m/s^2$ (d) $v=-4\hat{i}m/s, a=-8\hat{j}m/s^2$

70. A car is moving on a circular path of radius 600 m such that the magnitudes of the tangential and centripetal acceleration are equal. Time taken by the car to complete first quarter of revolution, if it is moving with an initial speed of 54 km/hr is $t(1-e^{-\pi/2})s$. The value of t is _____.
[29 Jan, 2023 (Shift-II)]

71. A stone tied to 180 cm long string at its end is making 28 revolutions in horizontal circle in every minute. The magnitude of acceleration of stone is $\frac{1936}{x}ms^{-2}$. The value of x _____.
$\left(\text{Take } \pi=\frac{22}{7}\right)$ [30 Jan, 2023 (Shift-II)]

72. A ball is spun with angular acceleration $\alpha=6t^2-2t$ where t is in second and α is in $rads^{-1}$. At $t=0$, the ball has angular velocity of 10 $rads^{-1}$ and angular position of 4 rad. The most appropriate expression for the angular position of the ball is: [28 June, 2022 (Shift-II)]
(a) $\frac{3}{2}t^4-t^2+10t$ (b) $\frac{t^4}{2}-\frac{t^3}{3}+10t+4$
(c) $\frac{2t^4}{3}-\frac{t^3}{6}+10t+12$ (d) $2t^4-\frac{t^3}{2}+5t+4$

73. Motion of a particle in $x-y$ plane is described by a set of following equations $x=4\sin\left(\frac{\pi}{2}-\omega t\right)$ m and $y=4\sin(\omega t)$m. The path of the particle will be: [28 June, 2022 (Shift-I)]
(a) Circular (b) Helical
(c) Parabolic (d) Elliptical

74. A fly wheel is accelerated uniformly from rest and rotates through 5 rad in the first second. The angle rotated by the fly wheel in the next second, will be: [24 June, 2022 (Shift-II)]
(a) 7.5 rad (b) 15 rad (c) 20 rad (d) 30 rad

75. A body rotating with an angular speed of 600rpm is uniformly accelerated to 1800rpm in 10 sec. The number of rotations made in the process is _____. [20 July, 2021 (Shift-II)]

OFFICE OBSE R @RY EDUCAT

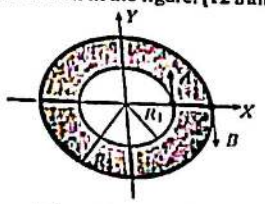
76. A particle moves such that its position vector $\vec{r}(t) = \cos\omega\,\hat{i} + \sin\omega t\,\hat{j}$ where ω is a constant and t is time. Then which of the following statements is true for the velocity $\vec{v}(t)$ and acceleration $\vec{a}(t)$ of the particle: **[8 Jan, 2020 (Shift-II)]**

(a) $\vec{v}$ is perpendicular to $\vec{r}$ and $\vec{a}$ is directed towards the origin.
(b) $\vec{v}$ and $\vec{a}$ both are parallel to $\vec{r}$.
(c) $\vec{v}$ is perpendicular to $\vec{r}$ and $\vec{a}$ is directed away from the origin.
(d) $\vec{v}$ and $\vec{a}$ both are perpendicular to $\vec{r}$.

77. A particle is moving along a circular path with a constant speed of 10 ms^{-1}. What is the magnitude of the change in velocity of the particle, when it moves through an angle of 60° around the centre of the circle? **[11 Jan, 2019 (Shift-I)]**

(a) $10\sqrt{3}$ m/s (b) 0
(c) $10\sqrt{2}$ m/s (d) 10 m/s

78. Two particles A, B are moving on two concentric circles of radii R_1 and R_2 with equal angular speed ω. At $t = 0$, their positions and direction of motion are shown in the figure: **[12 Jan, 2019 (Shift-II)]**



The relative velocity $\overrightarrow{v_A} - \overrightarrow{v_B}$ at $t = \frac{\pi}{2\omega}$ is given by:

(a) $\omega(R_1 + R_2)\hat{i}$ (b) $-\omega(R_1 + R_2)\hat{i}$
(c) $\omega(R_2 - R_1)\hat{i}$ (d) $\omega(R_1 - R_2)\hat{i}$

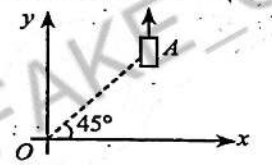
JEE-Advanced

Position, Distance and Displacement

Subjective

1. On a frictionless horizontal surface, assumed to be the $x-y$ plane, a small trolley A is moving along a straight line parallel to the y-axis (see figure) with a constant velocity of $(\sqrt{3}-1)$m/s. At a particular instant when the line OA makes an angle of 45° with the x-axis, a ball is thrown along the surface from the origin O. Its velocity makes an angle ϕ with the x-axis and it hits the trolley.

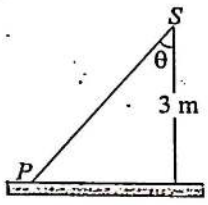
(a) The motion of the ball is observed from the frame of the trolley. Calculate the angle θ made by the velocity vector of the ball with the x-axis in this frame.



(b) Find the speed of the ball with respect to the surface, if $\phi = 4\theta/3$. **(IIT-JEE 2002)**

Fill in the Blanks

2. Spotlight S rotates in a horizontal plane with constant angular velocity of 0.1 rad/s. The spot of light P moves along the wall at a distance of 3m. The velocity of the spot P when $\theta = 45°$ (see fig.) is..... m/s. **(IIT-JEE 1987)**



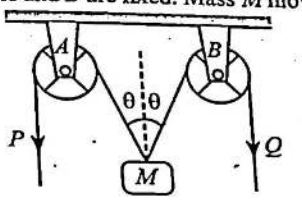
3. Four persons K, L, M, N are initially at the four corners of a square of side d. Each person now moves with a uniform speed v in such a way that K always moves directly towards L, L directly towards M, M directly towards N and N directly towards K. The four persons will meet at a time ..... **(IIT-JEE 1984)**

4. A particle moves in a circle of radius R. In half the period of revolution, its displacement is ... and distance covered is .... **(IIT-JEE 1983)**

Speed and Velocity

Single Correct

5. In the arrangement shown in the figure, the ends P and Q of an unstretchable string move downwards with uniform speed U. Pulleys A and B are fixed. Mass M moves upwards with a speed



(IIT-JEE 1982)

(a) $2U\cos\theta$ (b) $\frac{U}{\cos\theta}$ (c) $2U\cos\theta$ (d) $U\cos\theta$

Multiple Correct

6. The coordinates of a particle moving in a plane are given by $x(t) = a\cos(pt)$ and $y(t) = b\sin(pt)$ where a, $b(< a)$ and p are positive constants of appropriate dimensions. Then, **(IIT-JEE 1999)**

(a) The path of the particle is an ellipse
(b) The velocity and acceleration of the particle are normal to each other at $t = \pi/2p$
(c) The acceleration of the particle is always directed towards a focus
(d) The distance traveled by the particle in time interval $t = 0$ tc $t = \pi/2p$ is a

@FAKE_OPSEX@RAJ_ONLINET

Constant Acceleration

Single Correct

7. A particle is moving Eastwards with a velocity of 5 m/s. In 10 s, the velocity changes to 5 m/s Northwards. The average acceleration in this time is (IIT-JEE 1982)

(a) Zero

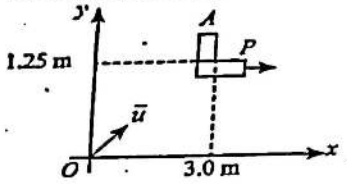
(b) $\frac{1}{\sqrt{2}}$ m/s² towards North-East

(c) $\frac{1}{\sqrt{2}}$ m/s² towards North-West

(d) $\frac{1}{2}$ m/s² towards North

Subjective

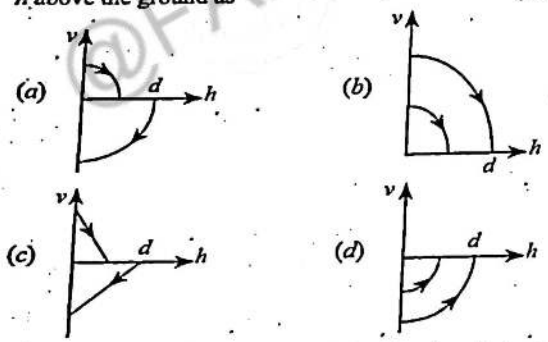
8. An object A is kept fixed at the point $x = 3$ m and $y = 1.25$ m on a plank P raised above the ground. At time $t = 0$, the plank starts moving along the $+x$-direction with an acceleration 1.5 m/s². At the same instant, a stone is projected from the origin with a velocity u as shown. A stationary person on the ground observes the stone hitting the object during its downward motion at an angle of 45° to the horizontal. All the motions are in $x-y$ plane. Find u and the time after which the stone hits the object. (Take $g = 10$ m/s²). (IIT-JEE 2000)



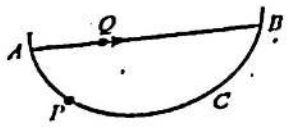
Motion Under Gravity

Single Correct

9. A ball is dropped vertically from a height d above the ground. It hits the ground and bounces up vertically to a height $d/2$. Neglecting subsequent motion and air resistance, its velocity v varies with height h above the ground as (IIT-JEE 2000)



10. A particle P is sliding down a frictionless hemispherical bowl. It passes the point A at $t = 0$. At this instant of time, the horizontal component of its velocity is v. A bead Q of the same mass as P is ejected from A at $t = 0$ along the horizontal string AB, with the speed v. Friction between the bead and the string may be neglected. Let t_P and t_Q be the respective times taken by P and Q to reach the point B.



(IIT-JEE 1993)

Then

(a) $t_P < t_Q$

(b) $t_P = t_Q$

(c) $t_P > t_Q$

(d) $\frac{t_P}{t_Q} = \frac{\text{length of arc } ACB}{\text{length of chord } AB}$

Numerical Types

11. A body falling freely from a given height H hits an inclined plane in its path at a height h. As a result of this impact the direction of the velocity of the body becomes horizontal. For what value of (h/H), the body will take maximum time to reach the ground? (IIT-JEE 1986)

True/False

12. Two balls of different masses are thrown vertically upwards with the same speed. They pass through the point of projection in their downward motion with the same speed (Neglect air resistance). (IIT-JEE 1983)

Projectile Motion: Ground To Ground Projection

Single Correct

13. A train is moving along a straight line with a constant acceleration a. A boy standing in the train throws a ball forward with a speed of 10 m/s, at an angle of 60° to the horizontal. The boy has to move forward by 1.15 m inside the train to catch the ball back at the initial height. The acceleration of the train, in m/s², is. (IIT-JEE 2011)

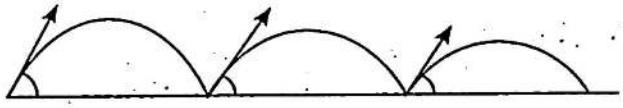
(a) 2 m/s² (b) 4 m/s² (c) 3 m/s² (d) 5 m/s²

Numerical Types

14. A projectile is fired from horizontal ground with speed v and projection angle θ. When the acceleration due to gravity is g, the range of the projectile is d. If at the highest point in its trajectory, the projectile enters a different region where the effective acceleration due to gravity is $g' = \frac{g}{0.81}$ then the new range is $d' = nd$. The value of n is_____.

C 12.85 W 67.44 UA 19.71 (JEE Adv. 2022)

15. A ball is thrown from ground at an angle θ with horizontal and with an initial speed u_0. For the resulting projectile motion, the magnitude of average velocity of the ball up to the point when it hits the ground for the first time is V_1. After hitting the ground, ball rebounds at the same angle θ but with a reduced speed of u_0/α. Its motion continues for a long time as shown in figure. If the magnitude of average velocity of the ball for entire duration of motion is $0.8\ V_1$, the value of α is___ C-17.79 W-62.13 UA-20.07 (JEE Adv. 2019)



@FREE CBSE X @RAJ EDUNET

Fill in the Blanks

16. The trajectory of a projectile in a vertical plane is $y = ax - bx^2$, where a, b are constants, and x and y are respectively, the horizontal and vertical distances of the projectile from the point of projection. The maximum height attained is..... and the angle of projection from the horizontal is.... **(IIT-JEE 1997)**

True/False

17. A projectile fired from the ground follows a parabolic path. The speed of the projectile is minimum at the top of its path **(IIT-JEE 1984)**

Comprehension Based/Statement Based

Question Stem for Question Nos. 22 and 23:

A projectile is thrown from a point O on the ground at an angle 45° from the vertical and with a speed $5\sqrt{2}$ m/s. The projectile at the highest point of its trajectory splits into two equal parts. One part falls vertically down to the ground 0.5 s after the splitting. The other part, t seconds after the splitting, falls to the ground at a distance x meters from the point O. The acceleration due to gravity $g = 10$ m/s².

18. The value of t is _____. **(JEE Adv. 2021)**

19. The value of x is _____. **C-37 43W-50 49 UA-12 09**

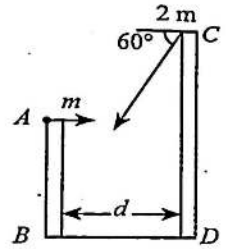
C-18 78 W-68 69 UA-12 53

Projectile Thrown From Some Height Above Ground

Subjective

20. Two guns situated on the top of a hill of height 10 m fire one shot each with the same speed $5\sqrt{3}$ m/s at some interval of time. One gun fires horizontally and other fires upwards at an angle of 60° with the horizontal. The shots collide in air at point $P(g = 10$ m/s$^2)$.
    (*a*) Find the time interval between the firings and
    (*b*) The coordinates of the point P. Take origin of the coordinate system at the foot of the hill right below the muzzle and trajectories in $x - y$ plane. **(IIT-JEE 1996)**

21. Two towers AB and CD are situated a distance d apart as shown in figure. AB is 20 m high and CD is 30 m high from the ground. An object of mass m is thrown from the top of AB horizontally with a velocity of 10 m/s towards CD.
    Simultaneously, another object of mass 2 m is thrown from the top of CD at an angle of 60° to the horizontal towards AB with the same magnitude of initial velocity as that of the first object. The two objects move in the same vertical plane, collide in mid-air and stick to each other. **(IIT-JEE 1994)**



    (*a*) Calculate the distance d between the towers.
    (*b*) Find the position where the objects hit the ground.

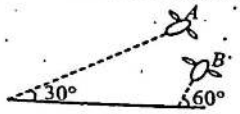
One Dimensional Relative Motion

Single Correct

22. **Statement-I:** For an observer looking out through the window of a fast moving train, the nearby objects appear to move in the opposite direction to the train, while the distant objects appear to be stationary.
    Statement-II : If the observer and the object are moving at velocities v_1 and v_2, respectively with reference to a laboratory frame, the velocity of the object with respect to the observer is $v_2 - v_1$ **(IIT-JEE 2008)**
    (*a*) Statement-I is true, Statement-II is true; Statement-II is the correct explanation for Statement-I
    (*b*) Statement-I is the, Statement-II is true; Statement-II is not a correct explanation for Statement-I
    (*c*) Statement-I is true; Statement-II is false
    (*d*) Statement-I is false; Statement-II is the

Numerical Types

23. Airplanes A and B are flying with constant velocity in the same vertical plane at angles 30° and 60° with respect to the horizontal respectively as shown in the figure. The speed of A is $100\sqrt{3}$ ms^{-1}. At the time $t = 0$s, an observer in A finds B at a distance of 500 m. This observer sees B moving with a constant velocity perpendicular to the line of motion of A. If at $t = t_0$, A just escapes being hit by B, t_0 in seconds is **C-28.28 W-59.26 UA-12.46 (JEE Adv. 2014)**



Subjective

24. A cart is moving along x-direction with a velocity of 4 m/s. A person on the cart throws a stone with a velocity of 6 m/s relative to himself. In the frame of reference of the cart, the stone is thrown in $y - z$ plane making an angle of 30° with vertical z-axis. At the highest point of its trajectory, the stone hits an object of equal mass hung vertically from branch of a tree by means of a string of length L.
    A completely inelastic collision occurs, in which the stone gets embedded in the object. Determine ($g = 9.8$ m/s²)
    (*a*) the speed of the combined mass immediately after the collision with respect to an observer on the ground.
    (*b*) the length L of the string such that tension in the string becomes zero when the string becomes horizontal during the subsequent motion of the combined mass. **(IIT-JEE 1997)**

Two Dimensional Relative Motion

Single Correct

25. A boat which has a speed of 5 km/h in still water crosses a river of width 1 km along the shortest possible path in 15 min. The velocity of the river water in km/h is **(IIT-JEE 1998)**
    (*a*) 1 (*b*) 3 (*c*) 4 (*d*) $\sqrt{41}$

FREE CBSE @RAJ_KUMAR_NET

26. A river is flowing from West to East at a speed of 5 m/min. A man on the South bank of the river, capable of swimming at 10 m/min in still water, wants to swim across the river in the shortest time. He should swim in a direction (IIT-JEE 1983)

(a) Due North (b) 30° East of North

(c) 30° West of North (d) 60° East of North

Multiple Correct

27. Starting at time $t = 0$ from the origin with speed 1 ms^{-1}, a particle follows a two-dimensional trajectory in the x-y plane so that its coordinates are related by the equation $y = \frac{x^2}{2}$. The x and y components of its acceleration are denoted by a_x and a_y, respectively. Then C-4.54 W-0 UA-33.55 PC-61.91 (JEE Adv. 2020)

(a) $a_x = 1$ ms^{-2} implies that when the particle is at the origin, $a_y = 1$ ms^{-2}

(b) $a_x = 0$ implies $a_y = 1$ ms^{-2} at all times

(c) at $t = 0$, the particle's velocity points in the x-direction

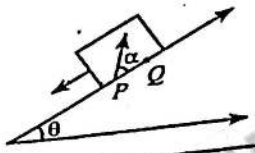
(d) $a_x = 0$ implies that at $t = 1s$, the angle between the particle's velocity and the x axis is 45°

Subjective

28. A large heavy box is sliding without friction down a smooth plane of inclination 0. From a point P on the bottom of the box, a particle is projected inside the box. The initial speed of the particle with respect to the box is u and the direction of projection makes an angle α with the bottom as shown in the figure. (IIT-JEE 1984)

(a) Find the distance along the bottom of the box between the point of projection P and the point Q where the particle lands. (Assume that the particle does not hit any other surface of the box. Neglect air resistance.)

(b) If the horizontal displacement of the particle as seen by an observer on the ground is zero, find the speed of the box with respect to the ground at the instant when the particle was projected.



@FAKE_CBSE X @RAJ_EDUNET

ANSWER KEY

JEE-Main

1. (d)	2. [673]	3. (d)	4. [2]	5. (b)	6. [580]	7. (d)	8. (d)	9. (a)	10. (c)
11. (b)	12. (a)	13. (d)	14. (Bonus)	15. (a)	16. [16]	17. (b)	18. (c)	19. (b)	20. (a)
21. (a)	22. (b)	23. (a)	24. (d)	25. (c)	26. (c)	27. [80]	28. [80]	29. (d)	30. (d)
31. (a)	32. (b)	33. (c)	34. (d)	35. (d)	36. (d)	37. (b)	38. [20]	39. [5]	40. [15or75]
41. (c)	42. (c)	43. [1]	44. (b)	45. (a)	46. (c)	47. (b)	48. (d)	49. [4.00]	50. [2]
51. [100]	52. (b)	53. (a)	54. (b)	55. [3]	56. [60]	57. (c)	58. (c)	59. (a)	60. [30]
61. [120]	62. [5]	63. (d)	64. (d)	65. (a)	66. [8]	67. (a)	68. [2]	69. (b)	70. [40]
71. [125]	72. (b)	73. (a)	74. (b)	75. [200]	76. (a)	77. (d)	78. (c)		

JEE-Advanced

1. (b)	2. (a, b, c)	5. (c)	7. (a)	8. (a)	9. [1/2]	10. [True]	11. (d)	12. [0.95]	13. [4.00]
15. [True]	16. [0.5]	17. [7.5]	20. (b)	22. [5]	24. (b)	25. (a)	27. (a, b, c, d)		

EXPLANATIONS

JEE-Main

1. (d) $\vec{v}=\frac{d\vec{s}}{dt}=4t\hat{j}$

Hence, velocity of ant at $t=1$ sec

$v=4\hat{j}$

2. [673] Given: $a_x=3$ m/s², $u_x=5$ m/s

$x=84$ m

$v_x^2-u_x^2=2ax$

$v_x^2-25=2(3)(84)\Rightarrow v_x=23$ m/s

Now, $v_x-u_x=a_xt \Rightarrow t=\frac{23-5}{3}=6$ s

$v_y=0+a_yt=0+2\times(6)=12$ m/s

$v^2=v_x^2+v_y^2=23^2+12^2=673$

$v=\sqrt{673}$ m/s

3. (d) Given: $x=2+4t$ ...(i)

$\frac{dx}{dt}=v_x=4$ and $\frac{dv_x}{dt}=a_x=0$

Now, $y=3t+8t^2$ ...(ii)

$\frac{dy}{dt}=v_y=3+16t$ and

$\frac{dv_y}{dt}=a_y=16$

Hence, the motion will be uniformly accelerated motion.

From path, $x=2+4t \Rightarrow t=\frac{x-2}{4}$

Put this value of t in equation (ii)

$y=3\left(\frac{x-2}{4}\right)+8\left(\frac{x-2}{4}\right)^2$

4. [2] $\vec{a}=\frac{\vec{F}}{m}=100\hat{i}+50\hat{j}$

$\vec{s}=\vec{u}t+\frac{1}{2}\vec{a}t^2$

$a\hat{i}+b\hat{j}=0+\frac{1}{2}(100\hat{i}+50\hat{j})\times4$

$=200\hat{i}+100\hat{j} \Rightarrow \frac{a}{b}=\frac{200}{100}=2$

5. (b) We have, $x=3t$ $y=5t^3$

$V_x=\frac{dx}{dt}=3 \Rightarrow V_y=\frac{dy}{dt}=15t^2$

$a_x=\frac{dV_x}{dt}=0 \Rightarrow a_y=\frac{dV_y}{dt}=30t$

$\vec{a}=a_x\hat{x}+a_y\hat{y}+a_z\hat{z}$

Since, z coordinate is constant. Therefore, $a_z=0$

$\vec{a}=30t\hat{j}$

at $t=1$ sec $\vec{a}=30\hat{j}$

6. [580] $X_1=-3t^2+8t+10$

$\vec{v}_1=(-6t+8)\hat{i}=2\hat{i}$

$Y_2=5-8t^3$

$\vec{v}_2=-24t^2\hat{j}$

$\sqrt{v}=|\vec{v}_2-\vec{v}_1|=|-24\hat{j}-2\hat{i}|$

$\sqrt{v}=\sqrt{24^2+2^2}$

$v=580$ m/s

7. (d) $S_y=u_yt+\frac{1}{2}a_yt^2$

$32=0+\frac{1}{2}\times4t^2 \Rightarrow t=4$ sec

$S_x=u_xt+\frac{1}{2}a_xt^2$

$=3\times4+\frac{1}{2}\times6\times16=60$ m.

8. (d) At $t=t$, (20 m, y_0)

$u=5$i m/s

$a_x=10$i

$a_y=4$i

$x=a_xt^2$

$\therefore t=\sqrt{\frac{20\times2}{10}}=2s$.

$\therefore y_0=5\times2+\frac{1}{2}\times4\times2^2=18$ m.

9. (a) $\frac{h_1}{d}=\tan45°$

$\frac{h_1+h_2}{d+2.464d}=\tan30° \Rightarrow h_2=d$

10. (c) $\frac{dx}{dt}=y; \frac{dy}{dt}=x$

$\frac{dx}{dy}=\frac{y}{x} \Rightarrow y^2=x^2+c$

11. (b) $\vec{s}=(5\hat{i}+4\hat{j})2+\frac{1}{2}(4\hat{i}+4\hat{j})4$

$=10\hat{i}+8\hat{j}+8\hat{i}+8\hat{j}$

$\Rightarrow \vec{r}_2-\vec{r}_1=18\hat{i}+16\hat{j}$

$\vec{r}_2=20\hat{i}+20\hat{j} \Rightarrow |\vec{r}_f|=20\sqrt{2}$

12. (a) $v_x=\frac{dx}{dt}=-a\omega\sin\omega t$

$v_y=\frac{dy}{dt}=a\omega\cos\omega t \Rightarrow v_z=\frac{dz}{dt}=a\omega$

$\therefore v=\sqrt{v_x^2+v_y^2+v_z^2}=a\omega\sqrt{2}$

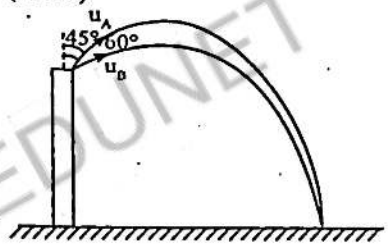
13. (d) $\vec{r}=15t^2\hat{i}+(4-20t^2)\hat{j}$

$\vec{v}=\frac{d\vec{r}}{dt}=30t\hat{i}+(-40t)\hat{j}$

$\vec{a}=\frac{d\vec{v}}{dt}=30\hat{i}-40\hat{j}$

$|\vec{a}|=50$ m/s²

14. (Bonus)



For u_A & u_B time of flight and range can not be same. So above options are incorrect.

15. (a) Maximum height $H=\frac{v^2\sin^2\theta}{2g}$

$4R=\frac{4\pi^2R^2}{T^2 2g}\sin^2\theta \quad \left[\therefore \frac{2\pi R}{T}=V\right]$

$\Rightarrow \sin\theta=\sqrt{\frac{2gT^2}{\pi^2R}}$

$\Rightarrow \theta=\sin^{-1}\left(\frac{2gT^2}{\pi^2R}\right)^{\frac{1}{2}}$

16. [16] For projectile maximum height,

$H_{max}=\frac{u^2\sin^2\theta}{2g}$

$\frac{H_{1max}}{H_{2max}}=\frac{u_1^2}{u_2^2}$

$\frac{64}{H_{2max}}=\frac{u^2}{(u/2)^2}$

$H_{2max}=16$ m

17. (b) Here horizontal range and maximum height is same. so,

$\frac{u^2\sin2\theta}{g}=\frac{u^2\sin^2\theta}{2g}$

$4\sin\theta\cos\theta=\sin^2\theta$

$4=\tan\theta$

@FAKE_CBSE_X @RAJ_EDUNET

18. (c) Range, $R = \frac{u^2 \sin 2\theta}{g} \Rightarrow R \propto \sin(2\theta)$

$$\frac{R_1}{R_2} = \frac{\sin(2\theta_1)}{\sin(2\theta_2)} = \frac{\sin(2\times 15^\circ)}{\sin(2\times 45^\circ)} = \frac{\sin 30^\circ}{\sin 90^\circ}$$

$$= \frac{1}{2}$$

$R_2 = 2R_1 = 2 \times 50 = 100\ m$

19. (b) Velocity of the projectile at the highest point $= u\cos\theta$

$$u\cos\theta = \frac{\sqrt{3}u}{2}$$

$\Rightarrow \theta = 30^\circ$

Time of flight $T = \frac{2u\sin 30^\circ}{g} = \frac{u}{g}$

20. (a) $y = x - \frac{x^2}{20}$

For maximum height,

$$\frac{dy}{dx} = 0 \Rightarrow \frac{d}{dx}\left(x - \frac{x^2}{20}\right) = 0$$

$$1 - \frac{2x}{20} = 0$$

$x = 10$

So, $y_{max} = 10 - \frac{100}{20} = 5m$

21. (a) At the highest point
Vertical component of the velocity, $v_y = 0$
Horizontal component of the velocity

$v_x = u_x = u\cos\theta$

Gravitational potential energy
$U_g = mgh$, it is maximum at H_{max}.

22. (b) $R = \frac{u^2}{g}\sin 2\theta$

R is maximum for $2\theta = 90°$.
$\sin 2\theta = \sin 90° = 1$
$\because 2\theta = 90° \Rightarrow \theta = 45°$

23. (a) Horizontal component of velocity, v_x
$= u\cos 30° = 40 \times \frac{\sqrt{3}}{2} = 20\sqrt{3}$ m/s

Vertical component of velocity,
$v_y = u\sin 30°$

$= 40 \times \frac{1}{2} = 20$ m/s

At $t = 2$s, $v_x = u_x = 20\sqrt{3}$

$v_y = u_y - gt = 20 - 10 \times 2 = 0$

$\therefore \quad v = \sqrt{v_x^2 + v_y^2} = 20\sqrt{3} ms^{-1}$

24. (d) Range $= \frac{u^2 \sin 2\theta}{g}$

Range for angle of projection "α"

$R_1 = \frac{u^2 \sin 2\alpha}{g}$

Range for angle of projection "β"

$R_2 = \frac{u^2 \sin 2\beta}{g}$

Given, $\alpha + \beta = 90°$
$\Rightarrow \beta = 90° - \alpha$

$R_2 = \frac{u^2 \sin 2(90° - \alpha)}{g}$

$R_2 = \frac{u^2 \sin 2\alpha}{g}$

$\Rightarrow \frac{R_1}{R_2} = \frac{\left(\frac{u^2 \sin 2\alpha}{g}\right)}{\left(\frac{u^2 \sin 2\alpha}{g}\right)} = \frac{1}{1}$

25. (c) Maximum height

$H_{max} = \frac{u^2 \sin^2\theta}{2g} \Rightarrow H_{max} \propto \sin^2\theta$

$$\frac{H_1}{H_2} = \frac{\sin^2\theta_1}{\sin^2\theta_2} = \frac{\sin^2 30°}{\sin^2 60°} = \frac{(1/2)^2}{(\sqrt{3}/2)^2} = \frac{1}{3}$$

26. (c) Maximum vertical height is given by

$H_{max} = \frac{v^2}{2g} = 136m$

and maximum horizontal range is

$R_{max} = \frac{v^2}{g} = 2H_{max}$

$= 2(136)$
$\Rightarrow R_{max} = 272m$

27. [80] Time of flight $T_2 = 3 + 5 = 8$ sec
Formula of Time of flight,

$\therefore T = \frac{2u\sin 30°}{g}$

$u = \frac{Tg}{2\sin 30°}$

$u = \frac{8 \times 10}{2 \times \left(\frac{1}{2}\right)}$

$u = 80$ m/s

28. [80] For the same horizontal range if angle of projection for projectile 1 is 60° then angle of projectile 2 is 30° for same range

$H_1 = \frac{u^2 \sin^2 60°}{2g}, H_2 = \frac{u^2 \sin^2 30°}{2g}$

$H_1 + H_2 = \frac{u^2 \sin^2 60°}{2g} + \frac{u^2 \sin^2 30°}{2g}$

$= \frac{u^2}{2g} = \frac{40^2}{2\times 10} = 80$ m

Hence, the sum of the maximum heights attained by the two projectile is 80 m.

29. (d) At the maximum height velocity $= u\cos\theta = u\cos 30°$.

$$\frac{KE_{initial}}{KE_{top}} = \frac{\frac{1}{2}M(u)^2}{\frac{1}{2}M\left(u\cos 30^\circ\right)^2} = \frac{4}{3}$$

30. (d) $R_1 = \frac{u_1^2 \sin 2\theta_1}{g}; R_2 = \frac{u_2^2 \sin 2\theta_2}{g}$

$$\frac{R_1}{R_2} = \frac{40^2 \sin\left(2\times 30^\circ\right)}{60^2 \sin\left(2\times 60^\circ\right)} = \frac{4\sin 60°}{9\cos 30°} = \frac{4}{9}$$

31. (a) For first angle,

$\theta_1 = \theta$, Range, $R = \frac{u^2 \sin 2\theta}{g}$

Another angle ($\theta_2 = 90 - \theta$) for which range will be same as that of $\theta_1 = \theta$

$R^1 = \frac{u^2 \sin 2(90-\theta)}{g} = \frac{u^2}{g}\sin 2\theta = R$

at $\theta_1 = \theta$, $h_1 = \frac{u^2 \sin^2\theta}{2g}$

& $\theta_2 = 90 - \theta$, $h_2 = \frac{u^2 \sin^2\theta_2}{2g} = \frac{u^2 \cos^2\theta}{2g}$

$\Rightarrow h_1 h_2 = \left[\frac{u^2}{2g}\sin\theta\cos\theta\right]^2 = \left[\frac{u^2 \sin 2\theta}{4g}\right]^2$

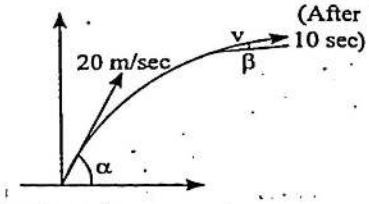
$\Rightarrow h_1 h_2 = \frac{1}{4^2}\left[\frac{u^2 \sin 2\theta}{g}\right]^2$

$h_1 h_2 = \frac{1}{4^2}R^2$

$R = 4\sqrt{h_1 h_2}$

Hence, Both statement is true & Reason is correct explanation for assertion.

32. (b) Throughout the motion, the horizontal speed will remain constant, therefore,



Along x-axis,
$u_x = v_x = 20\cos\alpha$ ...(i)
Along y-axis

@FAKE_CBSE_X @RAJ_EDUNET

$u_y = 20\sin\alpha$,

Applying Kinematic eqn.

$v_y = u_y + a_y t$

$v_y = 20\sin\alpha - 10 \times 10$ ...(ii)

$\tan\beta = \frac{v_y}{v_x} = \frac{20\sin\alpha - 100}{20\cos\alpha}$

$\Rightarrow \tan\beta = \tan\alpha - 5\sec\alpha$

33. (c) Range, $R = \frac{u^2 \sin 2\theta}{g}$

$R_1 = \frac{u^2 \sin 90^\circ}{g}$

$R_2 = \frac{u^2 \sin 60^\circ}{g}$

$\Rightarrow$ Required ratio, $\frac{R_1}{R_2} = \frac{2}{\sqrt{3}}$

34. (d) $y = x - \frac{10x^2}{2u^2\left(\frac{1}{2}\right)}$

$\Rightarrow 10 = 20 - \frac{(10)(400)}{u^2} \Rightarrow u = 20\,\text{m/s}$

$t = \frac{T}{\sqrt{2}} = \frac{(2)(20)\times\sin 45^\circ}{\sqrt{2}(10)} = 2s$

$\vec{v} = u\cos\theta\hat{i} + (u\sin\theta - gt)\hat{j}$

$= 10\sqrt{2}\,\hat{i} + \left(10\sqrt{2} - 10(2)\right)\hat{j}$

Momentum

$\vec{p} = M\vec{v} = 100\sqrt{2}\,\hat{i} + \left(100\sqrt{2} - 200\right)\hat{j}$

35. (d) $R = \frac{V^2(2\sin\theta\cos\theta)}{g}$

$t = \frac{V\sin\theta}{g} \Rightarrow V = \frac{gt}{\sin\theta}$

$\Rightarrow R = \frac{g^2t^2}{\sin^2\theta} \cdot \frac{2\sin\theta\cos\theta}{g}$

$\tan\theta = \frac{2gt^2}{R} = \frac{20t^2}{R}$

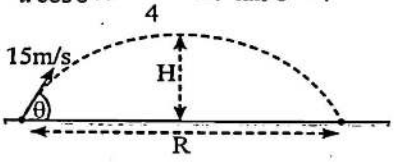
$\cot\theta = \frac{R}{20t^2}$

36. (d) $R = H$

$\frac{2v_x \times v_y}{g} = \frac{v_y^2}{2g}$

$v_x = \frac{v_y}{4}$;

$u\cos\theta = \frac{u\sin\theta}{4} \Rightarrow \tan\theta = 4$



37. (b) According to question, we can write

$R = \frac{u^2 \sin 2q}{g}$

For maximum range, (R_{max})

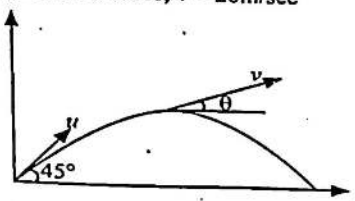
$\theta = 45^\circ$.

$R_{max} = \frac{u^2}{g} \Rightarrow u^2 = gR_{max}$

$\Rightarrow H_{max} = \frac{u^2}{2g} = \frac{gR_{max}}{2g} = \frac{R_{max}}{2}$

$= \frac{100}{2} = 50m$

38. [20] After 2 sec; v = 20m/sec



$\vec{v} = u\cos 45^\circ\hat{i} + (u\sin 45^\circ - gt)\hat{j}$

$\Rightarrow \vec{v} = u\cos 45^\circ\hat{i} + (u\sin 45^\circ - 20)\hat{j}$

$v = 20 = \sqrt{(u\cos 45^\circ)^2 + (u\sin 45^\circ - 20)^2}$

$\Rightarrow 400 = u^2 + 400 - 40u\sin 450^\circ$

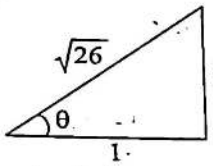
$\Rightarrow u = 40\sin 45^\circ$

$H_{max} = \frac{u^2\sin^2 45^\circ}{2g}$

$= \frac{40^2\sin^2 45^\circ \times \sin^2 45^\circ}{2g} = 20m$

39. [5] Given, $u_x = \hat{i}, |u_x| = 1$

$y = x5(1-x) = x\tan\theta\left(1 - \frac{x}{R}\right)$



$\tan\theta = 5, R = 1$

$\tan\theta = \frac{|u_x|}{|u_y|}$,

$|u_y| = |u_x|\tan\theta = 1 \times 5 = 5$ m/s

40. [15or75] $R = \frac{u^2\sin\left(2\times 45^\circ\right)}{g} = \frac{u^2}{g}$

$\frac{R}{2} = \frac{u^2}{2g} = \frac{u^2\sin 2\theta}{g}$

$\Rightarrow \sin 2\theta = \frac{1}{2} \Rightarrow \theta = 15^\circ, 75^\circ$

41. (c) At highest point, velocity

$V = u\cos 60^\circ = \frac{u}{2}$

K.E at topmost point $= \frac{1}{2}m\left(\frac{u}{2}\right)^2 = \frac{E}{4}$

42. (c) Time taken to reach maximum height

$t = \frac{u\sin\theta}{g}$ $\therefore \frac{u_1\sin\theta_1}{g} = \frac{u_2\sin\theta_2}{g}$

$\Rightarrow u_1\sin 30^\circ = u_2\sin 45^\circ$

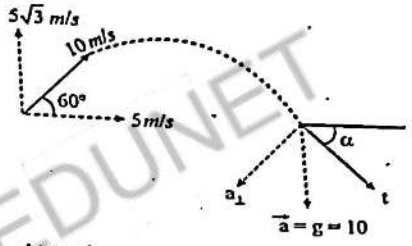
$\Rightarrow \frac{u_1}{u_2} = \frac{1/\sqrt{2}}{1/2} = \frac{\sqrt{2}}{1}$

43. [1] Time of flight is same

$\Rightarrow$ Vertical component of velocity is same

$\Rightarrow H_{max}$ is same

44. (b)



At $t = 1$

$u_x = 5, u_y = 5\sqrt{3}$

$v_y = 5\sqrt{3} - 10; v_x = 5$

Angle made by velocity vector at $t = 1$ sec.

$|\tan\alpha| = \left|\frac{v_y}{v_x}\right| = |2 - \sqrt{3}|$

$\alpha = 15^\circ$

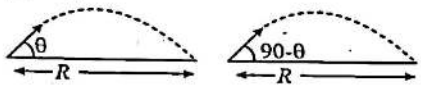
$\therefore R = \frac{5^2 + \left(10 - 5\sqrt{3}\right)^2}{10\cos\alpha} = \frac{200 - 100\sqrt{3}}{10\times 0.965}$

$= 2.8$ m

45. (a) Area $\propto \pi(\text{Range})^2 \propto u^4$

$\therefore \frac{A_1}{A_2} = \left(\frac{1}{2}\right)^4$

46. (c) Range will be same for time t_1 and t_2, so angles of projection will be 'θ' and '$90^\circ - \theta$'



$t_1 = \frac{2u\sin\theta}{g}$ $t_2 = \frac{2u\sin(90^\circ - \theta)}{g}$

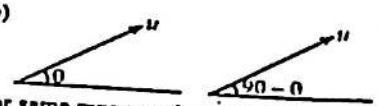
and $R = \frac{u^2\sin 2\theta}{g}$

$t_1t_2 = \frac{4u^2\sin\theta\cos\theta}{g^2} = \frac{2}{g}\left[\frac{2u^2\sin\theta\cos\theta}{g}\right]$

$= \frac{2R}{g}$

@FAKE_CBSE_X_@RAJ_EDUNET

47. (b)



For same range angle of projection will be θ & $90-\theta$

$$R=\frac{u^2 2\sin\theta\cos\theta}{g}$$

$$h_1=\frac{u^2\sin^2\theta}{2g}$$

$$h_2=\frac{u^2\sin^2(90-\theta)}{2g} \quad \therefore \frac{R^2}{h_1h_2}=16$$

48. (d) Equation of trajectory is given as

$y=2x-9x^2$ ... (I)

Comparing with equation:

$$y=x\tan\theta-\frac{g}{2u^2\cos^2\theta}\cdot x^2 \quad \text{... (II)}$$

We get; $\tan\theta=2$

$$\therefore \cos\theta=\frac{1}{\sqrt{5}}$$

Also, $\frac{g}{2u^2\cos^2\theta}=9$

$$\Rightarrow \frac{10}{2\times9\times\left(\frac{1}{\sqrt{5}}\right)^2}=u^2 \Rightarrow u^2=\frac{25}{9}$$

$$\Rightarrow u=\frac{5}{3}\text{ m/s}$$

49. [4.00]

$$\text{Average velocity}=\frac{\text{Total displacement}}{\text{Total time}}$$

Total time taken $=t_1+t_2+t_3+\ldots=t_1+\frac{t_1}{\alpha}+\frac{t_1}{\alpha^2}+\ldots$

$$\text{Total time}=\frac{t_1}{1-\frac{1}{\alpha}}$$

Total displacement $=v_1t_1+v_2t_2+\ldots l$

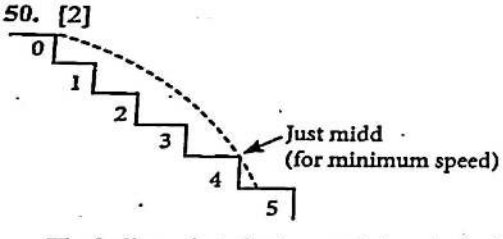
$$=v_1t_1+\frac{v_1}{\alpha}\cdot\frac{t_1}{\alpha}+\ldots=\frac{v_1t_1}{1-\frac{1}{\alpha^2}}$$

On solving

$$<v>=\frac{v_1\alpha}{\alpha+1}=0.8v_1$$

$\alpha=4.00$

50. [2]



The ball needs to just cross 4 steps to just hit 5th step

Therefore, horizontal range $(R)=0.4$ m

$R=u.t$

Similarly, in vertical direction

$$h=\frac{1}{2}gt^2$$

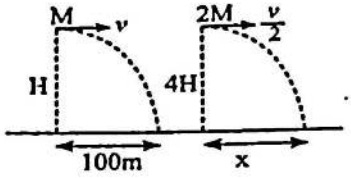
$$0.4=\frac{1}{2}R\left(\frac{0.4}{u}\right)^2$$

$u=\sqrt{2}$ m/s

Therefore, $x=2$

51. [100]

11 is the height at which the object is thrown

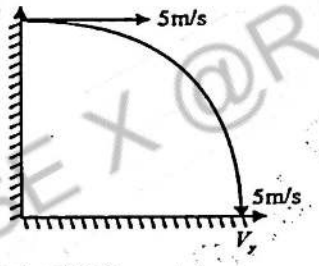


. this is the case of horizontal projectile

$$100=v\sqrt{\frac{2H}{g}};x=\frac{v}{2}\sqrt{\frac{2(4H)}{g}}=v\sqrt{\frac{2H}{g}}$$

$\Rightarrow x=100$

52. (b)



$v_x=u_x=5$ m/s

$v_y=\sqrt{2gh}=\sqrt{200}$

$v_{net}=\sqrt{v_x^2+v_y^2}$

$\Rightarrow v_{net}=\sqrt{25+200}=15$ m/s

53. (a) $t_0=\sqrt{\frac{2h}{g}} \Rightarrow V_0=\sqrt{\frac{2h}{g}}\times g=\sqrt{2gh}$

$\therefore t_1=$ time to reach top $=\frac{v_0}{g}$

$\Rightarrow H=h+h'=2h$

$\therefore t_2=$ time of fall $=\sqrt{\frac{2\times(2h)}{g}}=2\sqrt{\frac{h}{g}}$

$\therefore$ Total time $=t_1+t_2$

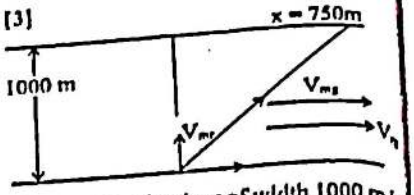
$$=(2+\sqrt{2})\sqrt{\frac{h}{g}}=3.4\sqrt{\frac{h}{g}}$$

54. (b) $t=\frac{2\times2\sin15^\circ}{g\cos30^\circ}$

$S=2\cos15^\circ\times t-\frac{1}{2}g\sin30^\circ t^2$

Put values and solve: $S=20$ cm

55. [3]



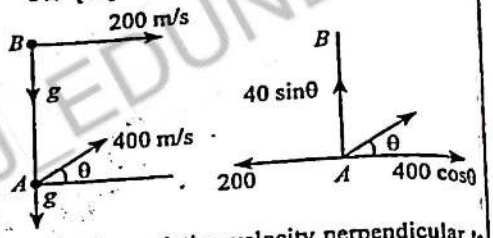
time to cross the river of width 1000 m $t_1=\frac{1\text{ km}}{4\text{ km/h}}$

Drift $x=V_{rs}\times t$

Where V_{rs} is velocity of river w.r. to ground. $x=V_{rs}\times\frac{1}{4}$

$V_{rs}=3$km/hr

56. [60] If A hits B



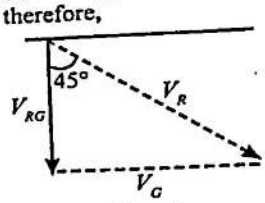
Then relative velocity perpendicular to the line joining A to B will be zero.

$\Rightarrow 400\cos\theta=200$

$\cos\theta=\frac{1}{2}$

$\theta=60^\circ$

57. (c) Let V_{RG} be velocity of rain w.r.t. girl therefore,



$$\theta=\tan^{-1}\left(\frac{V_G}{V_{RG}}\right)$$

$$45^\circ=\tan^{-1}\left(\frac{15\sqrt{2}}{V_{RG}}\right)$$

$$\tan45^\circ=\frac{15\sqrt{2}}{V_{RG}}$$

$$VRG=15\sqrt{2}=15\times\frac{\sqrt{2}}{\sqrt{2}}\times\sqrt{2}=\frac{30}{\sqrt{2}}\,km\,h^{-1}$$

58. (c) Given $\frac{v'}{v}=\tan60^\circ$

@FAKE_CBSE X @RAJEDUNET

$$\frac{v'}{v(1+\beta)} = \tan 45° \quad \text{...(ii)}$$

From (i) and (ii)

$\beta = 0.73$

59. (a)

$\vec{v}_{BW} = 4\sqrt{2}(\cos 45°\hat{i} + \sin 45°\hat{j}) = 4\hat{i} + 4\hat{j}$, and $\vec{v}_{WE} = 0\hat{i} - \hat{j}$

Resultant velocity of butterfly,

$\vec{v}_{BE} = \vec{v}_{BW} + \vec{v}_{WE} = (4\hat{i} + 4\hat{j}) + (0\hat{i} - \hat{j})$

$= 4\hat{i} + 3\hat{j}$

$\therefore$ Speed of butterfly $= |\vec{v}_{BE}| = 5$m/s

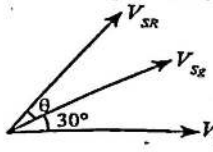
Magnitude of displacement of Butterfly

$= |\vec{v}_{BE}| \times t = 5 \times 3 = 15$m

60. [30] Both velocity vector are of same magnitude. Therefore resultant would pass exactly midway through them.

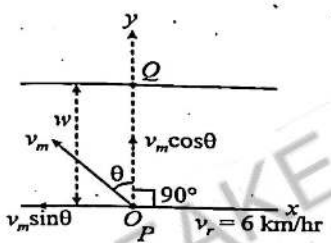
So, $\theta = 30°$

Hence, angle θ with the line AB is 30°



61. [120] Here, $v_m \sin\theta = v_r$

$\Rightarrow \sin\theta = \frac{1}{2}$



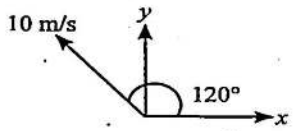
$\therefore \theta = 30°$

Since $\alpha = 90° + \theta$

$\Rightarrow \alpha = 120°$

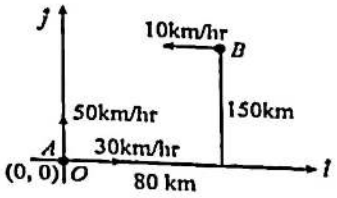
62. [5] We have,

$90° + \theta = 120° \Rightarrow \theta = 30°$



$\sin 30° = \frac{u}{v} \Rightarrow \frac{u}{10} = \frac{1}{2} \Rightarrow u = 5$ m/s

63. (d) If we take the position of ship 'A' as origin then positions and velocities of both ships can be given as:



$\vec{v}_A = (30\hat{i} + 50\hat{j})$ km/hr

$\vec{v}_B = -10\hat{i}$ km/hr

$\vec{r}_A = 0\hat{i} + 0\hat{j}$

$\vec{r}_B = (80\hat{i} + 150\hat{j})$ km

Time after which distance between them will be minimum

$$t = -\frac{\vec{r}_{BA}\cdot\vec{v}_{BA}}{|\vec{v}_{BA}|^2};$$

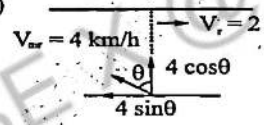
where $\vec{r}_{BA} = (80\hat{i} + 150\hat{j})$ km

$\vec{v}_{BA} = -10\hat{i} - (30\hat{i} + 50\hat{j}) = (-40\hat{i} - 50\hat{j})$ km/hr

$$\therefore \quad t = -\frac{(80\hat{i} + 150\hat{j})\cdot(-40\hat{i} - 50\hat{j})}{|-40\hat{i} + 50\hat{j}|^2}$$

$$= \frac{3200 + 7500}{4100} hr = \frac{10700}{4100} hr = 2.6 \text{ hrs}$$

64. (d)



For swimmer to cross the river straight

$\Rightarrow 4\sin\theta = 2$

$\Rightarrow \sin\theta = \frac{1}{2} \Rightarrow \theta = 30°$

So, angle with direction of river flow $= 90° + \theta = 120°$

65. (a) Given particles have same mass, so $m_1 = m_2$ and the ratio of radius of curvature

$$\frac{r_1}{r_2} = \frac{3}{4}$$

As centripetal force $F = \frac{mv^2}{r}$

In order to have constant (same in this question) centripetal force

$F_1 = F_2$

$$\frac{m_1 v_1^2}{r_1} = \frac{m_2 v_2^2}{r_2}$$

$$\Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{r_1}{r_2}} = \frac{\sqrt{3}}{2}$$

66. [8] Radius of circle, $r = 50$ cm

at $t = 0$, $v = 4$ m/s

$|\vec{a}_c| = |\vec{a}_t|$

$$\frac{v^2}{r} = \frac{dv}{dt} \Rightarrow \int_4^v \frac{dV}{v^2} = \int_0^t \frac{dt}{r} \Rightarrow \left[\frac{-1}{V}\right]_4^v = \frac{t}{r}$$

$$\Rightarrow \frac{-1}{v} + \frac{1}{4} = 2t \Rightarrow v = \frac{4}{1-8t} = \frac{ds}{dt}$$

$$4\int_0^t \frac{dt}{1-8t} = \int_0^s ds$$

$(r = 0.5$ m, $s = 2\pi r = \pi)$

$$4 \times \frac{\left[\ln(1-8t)\right]_0^t}{-8} = \pi$$

$\ln(1-8t) = -2\pi$

$1 - 8t = e^{-2\pi}$

$t = (1 - e^{-2\pi})\frac{1}{8}$ s

So, $\alpha = 8$

67. (a) $x_{min} = \pi \times r_{min} = \pi \times \frac{60}{100} m$

$x_{second} = 30 \times 2\pi \times r_{second}$

$= 30 \times 2\pi \times \frac{75}{100}$

$x = x_{second} - x_{min} = 139.4$ m

68. [2] centripetal acceleration, $a_c = \omega^2 x$

$$\frac{v dv}{dx} = \omega^2 x$$

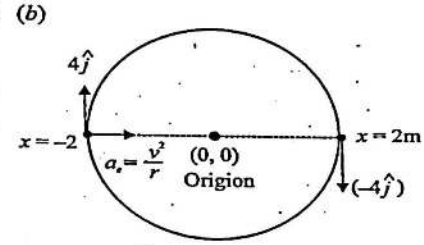
$$\int_0^v v dv = \int_1^3 \omega^2 x dx$$

$$\frac{v^2}{2} = \omega^2\left[\frac{x^2}{2}\right]$$

$$\frac{v^2}{3} = \frac{\omega^2}{2}\left[3^2 - 1^2\right] \Rightarrow v = 2\sqrt{2}\omega$$

$x = 2$

69. (b)



Centripetal acceleration is given by

$$a_c = \frac{v^2}{r} = \frac{4^2}{2} = 8 m/s^2$$

Using the above diagram

$\vec{v} = 4\hat{j}$

and, $\overrightarrow{a_c} = 8\hat{i}$

70. [40] $\because a_c = \frac{v^2}{R}$

@FAKE_CBSE_@RAJ_EDUNET

$$v\frac{dv}{dx}=\frac{v^2}{R}$$

$$\Rightarrow \int_{15}^{v}\frac{dv}{v}=\frac{1}{R}\int_0^x dx$$

$$\Rightarrow v=15e^{x/R}$$

$$\because \frac{dx}{dt}=15e^{x/R} \quad \left[\because v=\frac{dx}{dt}\right]$$

arranging the terms and integrating both sides

$$\int_0^{\frac{aR}{2}} e^{-x/R}dx=15\int_0^{t_0}dt$$

$$\Rightarrow t_0=40(1-e^{-a/2R})$$

71. [125] As the stone is moving in a circular path, so the acceleration is

$$a=\omega^2R=\left(\frac{28\times 2\pi}{60}\right)^2\times 1.8$$

$$=\frac{1936\times 1.8}{225}$$

$$x=125$$

72. (b) $\alpha=\frac{d\omega}{dt}$

$$\Rightarrow \int_{10}^{\omega}d\omega=\int_0^t \alpha dt$$

$$\Rightarrow [\omega]_{10}^{\omega}=\int_0^t \alpha dt$$

$$\Rightarrow \omega-10=\int_0^t (6t^2-2t)dt$$

$$\omega=10+2t^3-t^2$$

$$\omega=2t^3-t^2+10$$

$$\frac{d\theta}{dt}=2t^3-t^2+10$$

$$\Rightarrow \int_0^{\theta}d\theta=\int_0^t (2t^3-t^2+10)dt$$

$$\Rightarrow \theta-4=\frac{t^4}{2}-\frac{t^3}{3}+10t$$

$$\therefore \theta=\frac{t^4}{2}-\frac{t^3}{3}+10t+4$$

73. (a) $x=4\sin\left(\frac{\pi}{2}-\omega t\right)=4\cos(\omega t)$ ...(I)

$y=4\sin(\omega t)$ ...(II)

From (I) and (II)

$$\cos^2\omega t+\sin^2\omega t=\left(\frac{x}{4}\right)^2+\left(\frac{y}{4}\right)^2=1$$

$$=x^2+y^2=(4)^2$$

74. (b) $\theta_1=\frac{1}{2}\alpha(1)^2=5$ rad

$\Rightarrow \alpha=10$ rad/sec^2

So $\theta_2=\frac{1}{2}\times 10\times 2\times 2=20$ rad

$\therefore \theta_2-\theta_1=20-5=15$ rad

75. [200] $\omega^2=\omega_0^2+2\alpha\theta \Rightarrow \left(\frac{2\pi}{60}\times 1800\right)^2$

$$=\left(\frac{2\pi}{60}\times 600\right)^2+2\left(\frac{2\pi}{60}\times\frac{1200}{10}\right)0$$

On solving, $\theta=\frac{80\pi\times 40\pi}{2\times 4\pi}=400\pi$ rad

Number of rotations $=\frac{\theta}{2\pi}=\frac{400\pi}{2\pi}=200$

76. (a) $\vec{r}=\cos\omega t\hat{i}+\sin\omega t\hat{j}$

$$\vec{v}=\frac{d\vec{r}}{dt}=\omega\left(-\sin\omega t\hat{i}+\cos\omega t\hat{j}\right)$$

$$\vec{a}=\frac{d\vec{v}}{dt}=-\omega^2(\cos\omega t\hat{i}+\sin\omega t\hat{j})$$

$\vec{a}=-\omega^2\vec{r}$

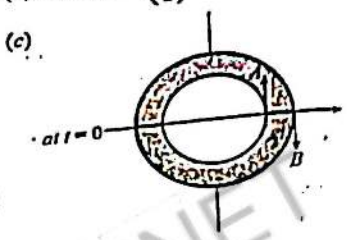
$\therefore$ $\vec{a}$ is antiparallel to $\vec{r}$

$\vec{v}.\vec{r}=\omega(-\sin\omega t\cos\omega t+\cos\omega t\sin\omega t)=0$

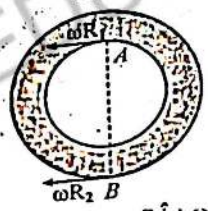
so $\vec{v}\perp\vec{r}$

77. (d) $\Delta\vec{v}=2v\sin\left(\frac{\theta}{2}\right)$

78. (c)



at $t=\frac{\pi}{2\omega}$



$$\vec{v}_A-\vec{v}_B=-\omega R_1\hat{i}+\omega.R_2\hat{i}=\omega(R_2-R_1)\hat{i}$$

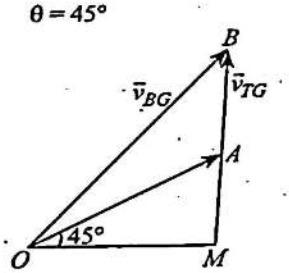
JEE-Advanced

1. (a) Let T stands for trolley and B for the ball.

From the triangle OAB

$\vec{v}_{BT}=\vec{v}_{BG}-\vec{v}_{TG}$ Relative velocity of B with respect to $T(v_{BT})$ should be along OA for the ball to hit the trolley. Hence, v_{BA} will make an angle of 45° with positive X-axis.

$\theta=45°$



(b) v_{BG} = velocity of ball w.r.t ground.

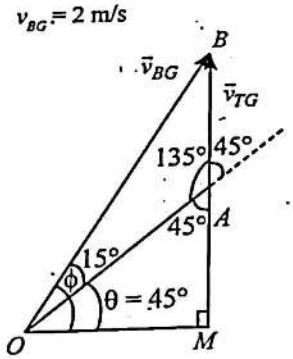
$\phi=\frac{4\theta}{3}=\frac{4}{3}(45°)=60°\rightarrow$ with x-axis

In triangle OAB using sine rule

$$\frac{v_{BG}}{\sin 135}=\frac{v_{TG}}{\sin 15}$$

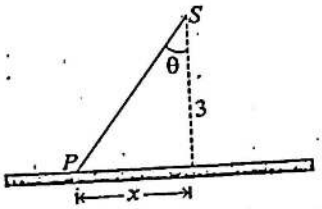
$$\frac{v_{BG}}{\sin 135}=\frac{(\sqrt{3}-1)\text{m/s}}{\sin 15}$$

$v_{BG}=2$ m/s



2. $\frac{x}{3}=\tan\theta$

$\therefore x=3\tan\theta$



$$-\left(\frac{dx}{dt}\right)=3\sec^2\theta\left(-\frac{d\theta}{dt}\right)$$

$-\frac{dx}{dt}=v_p$ and $-\frac{d\theta}{dt}$

$=\omega=0.1$ rad/s,

$\theta=45°$

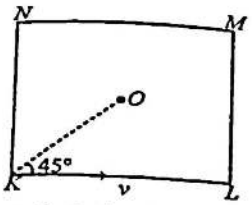
Substituting the values, we get

$v_p=3(\sec^2 45°)(0.1)$

$=0.6$ m/s

3. By symmetry, we can say that all will meet at the centre of square.

CRACKE_CBSE_X_@RAJ_EDUNET

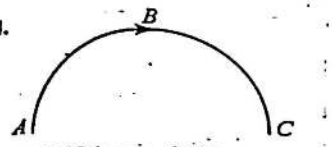


Component of velocity along KO (or LO etc) at any instant will be $v\cos 45°$ or $\frac{v}{\sqrt{2}}$.

Further distance $KO = \sqrt{2}\left(\frac{d}{2}\right) = \frac{d}{\sqrt{2}}$

$\therefore$ Time $= \frac{d/\sqrt{2}}{v/\sqrt{2}} = \frac{d}{v}$

4.



In Half time period it covers the circle.
Displacement $= AC = 2R$
Distance $= ABC = \pi R$

5. (*b*) Let the mass M is going up with velocity is V.
Then, a component along the thread is $V\cos\theta$
And it is given that the thread is moving with velocity U.
So, $V\cos\theta = U$

$$V = \frac{U}{\cos\theta}$$

6. (*a, b, c*) $x(t) = a\cos(pt)$ $y(t) = b\sin(pt)$

$$\cos(pt) = \frac{x(t)}{a} \quad \ldots(i)$$

$$\sin(pt) = \frac{y(t)}{b} \quad \ldots(ii)$$

Squaring and adding (*i*) and (*ii*)

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

So, the path is an ellipse.
From the given equation

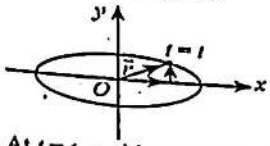
$$\frac{dx}{dt} = v_x = -ap\sin(pt)$$

$$\frac{dy}{dt} = v_y = bp\cos(pt)$$

$$\frac{d^2x}{dt^2} = a_x = -ap^2\cos(pt)$$

$$\frac{d^2y}{dt^2} = a_y = -bp^2\sin(pt)$$

At time $t = \pi/2p$ or $pt = \Pi/2$
a_x and v_y becomes zero ($\because \cos(\pi/2) = 0$)
Only v_x and a_y are left or we can say that velocity is along negative x-axis and acceleration is along y-axis
Hence, at $t = \pi/2p$ velocity and acceleration are normal.
So, option b is correct.



At $t = t$, position of the particle

$$r(t) = x\hat{i} + y\hat{j} = a\cos(pt)\hat{i} + b\sin(pt)\hat{j}$$

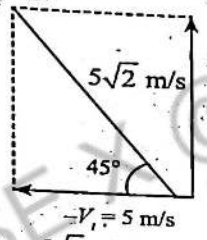
And acceleration pf the particle

$$a(t) = -p^2\left[a\cos(pt)\hat{i} + b\sin(pt)\hat{j}\right]$$

$$a(t) = -p^2 r(t)$$

Therefore, we can say that acceleration of particle is directed towards origin not a focus.
At $t = 0$ particle is at $(a, 0)$ and at $t = \pi/2p$ particle is at $(0, b)$. So the distance covered is 1/4 of elliptical path not a

7. (*c*) $\uparrow N$



$-V_1 = 5$ m/s
$\Delta v = 5\sqrt{2}$ m/s in North-West direction.

$$a_{av} = \frac{\Delta v}{\Delta t}$$

$$= \frac{5\sqrt{2}}{10} = \frac{1}{\sqrt{2}}\text{m/s}^2$$

S$\downarrow$ (in North-West direction)

8. Let t be the time after which the stone hits the object and θ be the angle which the velocity vector u makes with horizontal.
Given, displacement of stone in y-axis is 1.25 m.

$$1.25 = (u\sin\theta)t - \frac{1}{2}gt^2$$

$$(u\sin\theta)t = 1.25 + 5t^2 \quad \ldots(i)$$

Displacement of stone in x-axis =
Displacement of plank in x-axis

$$\therefore (u\cos\theta)t = 3 + \frac{1}{2}at^2 \text{; where, } a = 1.5\text{ m/s}^2$$

or $(u\cos\theta)t = 3 + 0.75t^2$ $\ldots(ii)$
Given that velocity vector is inclined at 45° with horizontal
Then we can say that,
Horizontal component of velocity of stone = vertical component of velocity of stone

$$(u\cos\theta) = gt - (u\sin\theta) \quad \ldots(iii)$$

Multiply by t to equation (*iii*)

$$(u\cos\theta)t + (u\sin\theta)t = 10t^2 \quad \ldots(iv)$$

And from equation (*i*) (*ii*) (*iv*)

$$3 + 0.75t^2 + 1.25 + 5t^2 = 10t^2$$

$$4.25t^2 - 4.25 = 0$$

$\therefore$ $t = 1$s
Substituting $t = 1$s in (*i*) and (*ii*) resp. we get
$u\sin\theta = 6.25$ m/s
Or $u_y = 6.25$ m/s
$u\cos\theta = 3.75$ m/s
or $u_x = 3.75$ m/s
Therefore, $u = u_x\hat{i} + u_y\hat{j}$ m/s
or $u = (3.75\hat{i} + 6.25\hat{j})$m/s

9. (*a*) (*i*) For motion under gravity

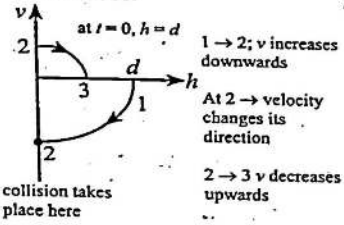
$$v^2 = u^2 - 2gh$$

Here $u = 0$, because ball is dropped with zero velocity

$$v^2 = -2gh$$

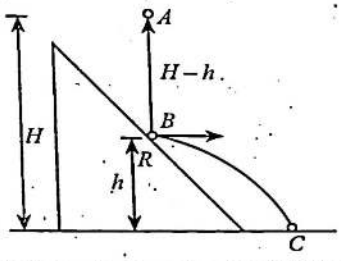
Since, it is like parabolic equation of left side facing parabola

(*ii*) Initially velocity of ball is downwards (-ve) and after the collision, it reverses its direction with magnitude less than earlier, i.e. velocity is upwards (+ve). Graph A satisfies both these conditions.



10. (*a*) Horizontal displacement for both the particle is equal to AC.
The velocity of particle Q is always equal to v. But the horizontal velocity of particle P is greater or equal to v.
Time is taken to cover the horizontal displacement $AC = AC$/horizontal speed of particle.

11. [1/2]



Let us take t_1 be the time taken by body from A to B and t_2 the time from B to C.

@FAKE_CBSE_T@RAJ_EDUNET

Using the equation of motion $s = ut + \frac{1}{2}at^2$ here $u = 0$, $a = g$

Then, $t_1 = \sqrt{\frac{2(H-h)}{g}}$ and $t_2 = \sqrt{\frac{2h}{g}}$

Then, the total time

$$t = t_1 + t_2 = \sqrt{\frac{2}{g}}\left[\sqrt{H-h} + \sqrt{h}\right]$$

For t to be maximum $\frac{dt}{dh} = 0$

$$\sqrt{\frac{2}{g}}\left[\frac{-1}{2\sqrt{H-h}} + \frac{1}{2\sqrt{h}}\right] = 0$$

$$\frac{1}{\sqrt{h}} = \frac{1}{\sqrt{H-h}}$$

$$2h = H$$

$$\frac{h}{H} = \frac{1}{2}$$

12. [True]

Acceleration due to gravity is same for both the masses because it is independent of the mass of the body. It is constant for all i.e. 9.8 m/s²

From the equation of motion

$v^2 = u^2 + 2as$; here $a = g$

And according to the condition given, when passing through point of projectile the value of $s = 0$.

$v = -u$

And u is same for both masses then v is also same.

13. (d) Time of flight of ball

$$= T = \frac{2u\sin\theta}{g} = \frac{2\times10\times\sin 60^\circ}{10} = \sqrt{3}\,s$$

Displacement of train in time T is $\frac{1}{2}aT^2$

Displacement of boy with respect to train = 1.15 m

∴ Displacement of boy with respect to ground

$$= \left(1.15 + \frac{1}{2}aT^2\right)$$

Displacement of the ball w.r.t. to ground $= (u\cos 60^\circ)T$

Condition for catching the ball back at its initial height,

$$1.15 + \frac{1}{2}aT^2 = \left(u\cos 60^\circ\right)T$$

$$\therefore\ 1.15 + \frac{1}{2}a(\sqrt{3})^2 = 10\times\frac{1}{2}\times\sqrt{3}$$

Solving this equation, we get

The acceleration of train, $a = 5$ m/s²

14. [0.95] $d = \frac{2v'^2\sin\theta\cos\theta}{g}$

$$d' = \frac{d}{2} + \sqrt{\frac{2H}{g'}}v\cos\theta$$

$$= \frac{d}{2} + \sqrt{\frac{2}{g'}\frac{v^2\sin^2\theta}{2g}}v\cos\theta$$

$$d' = \frac{d}{2} + \frac{v'^2\sin\theta\cos\theta}{\sqrt{g\frac{g}{0.81}}}$$

$$= \frac{d}{2} + \frac{d}{2}\left(\frac{9}{10}\right) = \frac{19d}{20} = 0.95d$$

15. [4.00]

Average velocity = $\frac{\text{Total displacement}}{\text{Total time}}$

Total time taken = $t_1 + t_2 + t_3 + \ldots$

$$= t_1 + \frac{t_1}{\alpha} + \frac{t_1}{\alpha^2} + \ldots$$

Total time = $\frac{t_1}{1-\frac{1}{\alpha}}$

Total displacement = $v_1t_1 + v_2t_2 + \ldots$

$$= v_1t_1 + \frac{v_1}{\alpha}\cdot\frac{t_1}{\alpha} + \ldots = \frac{v_1t_1}{1-\frac{1}{\alpha^2}}$$

On solving

$$\langle v\rangle = \frac{v_1\alpha}{\alpha+1} = 0.8v_1$$

$\alpha = 4.00$

16. $y = ax - bx^2$

For height (or y) to be maximum.

$$\frac{dy}{dx} = 0 = a - 2bx$$

$$\therefore\ x = \frac{a}{2b}$$

(i) $\therefore\ y_{max} = H$ = maximum height

$H = a(a/2b) - b(a/2b)^2$; $H = a^2/4b$

(ii) By comparing the given equation with equation of trajectory

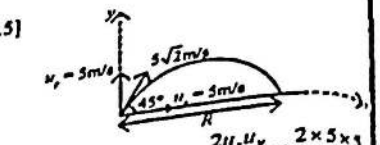
$$y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$$

$\tan\theta = a$ where, θ is the angle of projection.

$\therefore\ \theta = \tan^{-1}(a)$

17. [True] In a projectile motion under gravity, the horizontal velocity is always constant, and at the highest point, there is only horizontal velocity. Vertical velocity is zero, so the speed is low at the highest point of motion. From the conservation of mechanical energy, we can say that at the highest point, potential energy is maximum. Hence, the kinetic energy and speed should be minimum. So the statement is true.

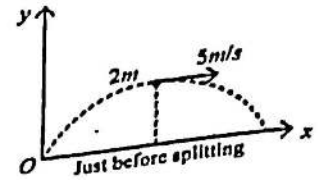
18. [0.5]



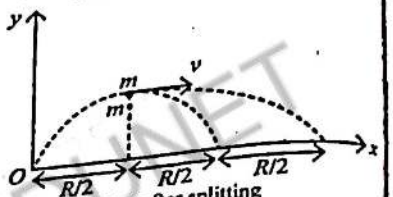
Range, $R = u_x \times T = \frac{2u_xu_y}{g} = \frac{2\times5\times3}{10}$

$= 5m$

Time of flight, $T = \frac{2u_y}{g} = \frac{2\times5}{10} = 1_s$



Just before splitting



Just after splitting

Both particle have no vertical velocity after splitting so both will take same time to reach the ground.

Time of motion of one part falling vertically downwards is 0.5s

⇒ Time of motion of another part, $t = 0.5$ s

19. [7.5] From momentum conservation, $p_i = p_f$

$2m \times 5 = m \times v$

$v = 10$ m/s

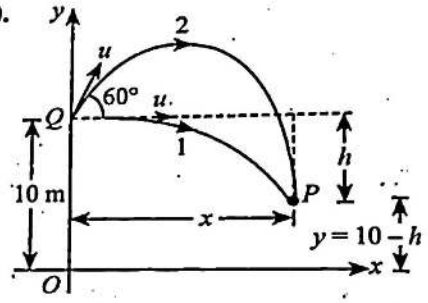
displacement of other part in 0.5s in horizontal direction,

$$= v\left(\frac{T}{2}\right) = 10 \times 0.5 = 5m = R$$

∴ Total distance of second part from point O is $x = \frac{3R}{2} = 3\times\frac{5}{2}$

$\Rightarrow x = 7.5m$

20.



$u = 5\sqrt{3}$m/s

@TAKE_CBSE_X @RAJ_EDUNET

$\therefore u\cos 60^\circ = \left(5\sqrt{3}\right)\left(\frac{1}{2}\right)\text{m/s} = 2.5\sqrt{3}\text{m/s}$

and $u\sin 60^\circ = \left(5\sqrt{3}\right)\left(\frac{\sqrt{3}}{2}\right)\text{m/s} = 7.5\text{m/s}$

Since, the horizontal displacement is equal for both shots. The second should be fired early because its horizontal component of velocity $u\cos 60^\circ$ or $2.5\sqrt{3}$m/s is less than the other which is u or $5\sqrt{3}$m/s.

Let the first shot takes t_1 time and the second t_2 to reach the point P.

Then, $x = (u\cos 60^\circ)\,t_2 = ut_1$

$\left(u\left(\frac{1}{2}\right)\right)t_2 = ut_1$

$t_2 = 2t_1$

$h = \left|(u\sin 60^\circ)t_2 - \frac{1}{2}gt_2^2\right| = \frac{1}{2}gt_1^2$

$h = \frac{1}{2}gt_2^2 - (u\sin 60^\circ)t_2 = \frac{1}{2}gt_1^2,\ g = 10\text{m/s}^2$

$\frac{1}{2}(10)t_2^2 - (u\sin 60^\circ)t_2 = \frac{1}{2}(10)t_1^2$

$(u\sin 60^\circ) = 7.5$ m/s

$5t_2^2 - 7.5t_2 = 5t_1^2$

Substituting $t_2 = 2t_1$ we get

$5(2t_1)^2 - 7.5(2t_1) = 5t_1^2$

or $15t_1^2 = 15t_1$

$t_1 = 1$s and $t_2 = 2t_1 = 2$s

(a) Time interval between the firings

$= t_2 - t_1 = (2-1)$s

$\Delta t = 1$s

(b) $x = ut_1 = 5\sqrt{3}t_1 = 5\sqrt{3}$ m

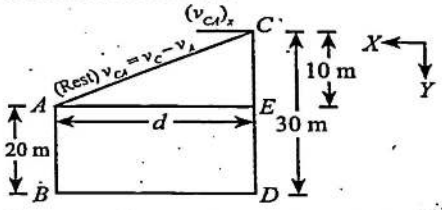
$h = \frac{1}{2}gt_1^2 = 5t_1^2 = 5(1)^2 = 5$m

$y = 10 - h = (10-5) = 5$ m

Coordinates of point

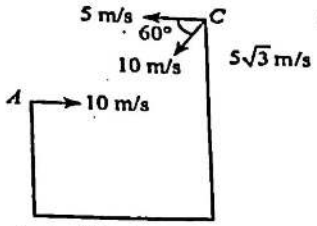
$P = (x, y) = (5\sqrt{3}\text{ m}, 5\text{m})$

21. Acceleration for the masses is g, so there is no relative acceleration



Now assuming A to be at rest, condition of collision will be that, $v_{CA} = v_C - v_A$

The relative velocity of C w.r.t. A should be along CA



$v_{CA} = -10$ m/s

$v_{Ay} = 0$

$v_{Cx} = 5$ m/s

$v_{Cy} = 5\sqrt{3}$ m/s

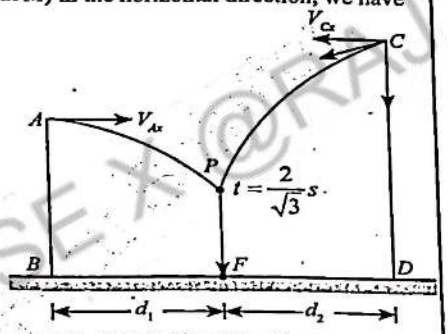
$\frac{(v_{CA})_y}{(v_{CA})_x} = \frac{CE}{AE} = \frac{10}{d}$

$\frac{v_{Cy} - v_{Ay}}{v_{Cx} - v_{Ax}} = \frac{10}{d}$

$\frac{5\sqrt{3} - 0}{5 - (-10)} = \frac{10}{d}$

$d = 10\sqrt{3} = 17.32$m

Applying the conservation of linear momentum (during collision of the masses at M) in the horizontal direction, we have



$m \times 10 - 2\text{ m} \times 10\cos 60 = 3\text{ m}v_x$

$10\text{ m} - 10\text{ m} = 3\text{ m}v_x$

$v_x = 0$

Time of collision, $t = \frac{AC}{|v_{CA}|}$

$|v_{CA}| = \sqrt{(v_{CAx})^2 + (v_{CAy})^2}$

$= \sqrt{\left[5 - (-10)\right]^2 + \left[5\sqrt{3} - 0\right]^2} = 10\sqrt{3}$ m/s

$v_{CA} = \sqrt{10^2 + \left(10\sqrt{3}\right)^2} = 20$

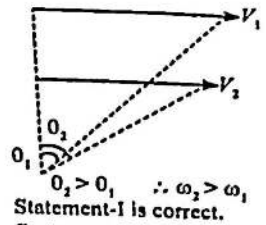
$t = \frac{20}{10\sqrt{3}} = \frac{2}{\sqrt{3}}s$

Since the horizontal momentum comes out to be zero, the combination of masses will drop vertically downwards and fall at F

$BF = d_1 = 10t = 10 \times \frac{2}{\sqrt{3}} = 11.55$ m

$d_2 = d - d_1 = 17.32 - 11.55 = 5.77$ m

22. (b)



$O_2 > O_1 \quad \therefore \omega_2 > \omega_1$

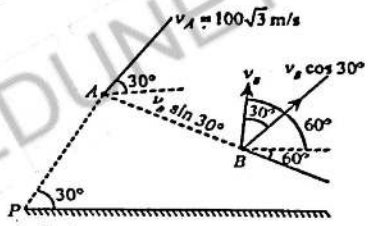
Statement-I is correct.

Statement-II is the formula of relative velocity, and it is correct statement.

But it does not explain Statement-I correctly.

The correct explanation of statement-I is due to the visual perception of motion. The nearby object appears to be moving faster when its angular velocity is greater w.r.t. observer as compared to distant objects.

23. [5]



Given that,

Observer in plane A observing that B is moving with a constant velocity perpendicular to the line of motion of A. It means their components of velocity in the direction of motion of A (PA) are equal

$v_A = v_B \cos 30°$

$100\sqrt{3} = v_B\frac{\sqrt{3}}{2}$

$v_B = 200$ m/s

And t_0 is the time when A just escapes being hit by B. By seeing the conditions their velocity in the direction of motion of A is same then we can say that

$t_0 = \frac{500}{v_B \sin 30°} = \frac{500}{200 \times 1/2} = 5$s

Relative velocity of B with respect to A is perpendicular to the line of motion of A that is PA. Therefore, along line PA, velocity components of A and B should be the same, So equating we get

$t_0 = 5$s

24. (a) Let $\hat{i}$, $\hat{j}$ and $\hat{k}$ be the unit vectors along x, y and z-directions respectively.

Given, $v_{cart} = 4\hat{i}$ m/s

$\therefore v_{stone,\,cart} = (6\sin 30°)\hat{j} + (6\cos 30°)\hat{k}$

$= (3\hat{j} + 3\sqrt{3}\hat{k})$m/s

$\therefore v_{stone} = v_{stone,\,cart} + v_{cart}$

$= (4\hat{i} + 3\hat{j} + 3\sqrt{3}\hat{k})$m/s

@FUKE_CBSE_X@RAJ_EDUNET

At highest point of its trajectory of stone, the vertical component (z) of its velocity will become zero, and the x and y-components of stone will remain unchanged. So, the velocity of stone at highest point will be,

$v = 4\hat{i} + 3\hat{j}$ m/s

or speed at highest point,

$v = |v| = (\sqrt{(4)^2 + (3)^2}$ m/s $= 5$ m/s

Now, applying law of conservation of linear momentum, let v_b be the velocity of combined mass after collision.

Then, $mv = (2\,m)\,v_b$

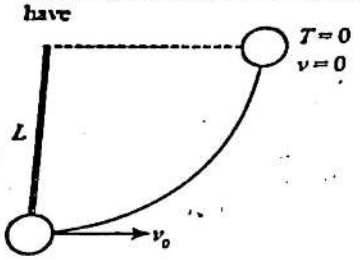
$\therefore v_b = \frac{v}{2} = \frac{5}{2}$ m/s $= 2.5$ m/s

$\therefore$ Hence, the speed of combined mass just after collision is 2.5 m/s.

(*b*) It is given that tension in the string becomes zero at horizontal position.

It means $T = \frac{mv^2}{L} = 0$. So the velocity of combined mass also becomes zero in horizontal position.

Applying conservation of energy, we have

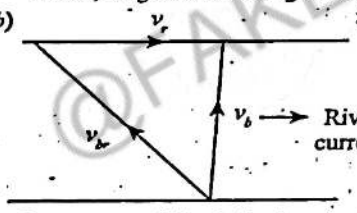


$\frac{1}{2}(2\text{m})v_0^2 = (2\text{m})gL$

$L = \frac{v_0^2}{2g} = \frac{(2.5)^2}{2(9.8)} = 0.32\,\text{m}$

Hence, length of the string is 0.32 m.

25. (*b*)



For shortest possible path, the absolute velocity of the boat should be perpendicular to river current

Time, $t = 15$ min $= (1/4)$hr

$v_{br} = 5$ km/h

ω = width of river = 1 km

v_r = velocity of river water = ?

$t = \frac{\omega}{v_b} = \frac{\omega}{\sqrt{v_{br}^2 - v_r^2}} \Rightarrow \frac{1}{4} = \frac{1}{\sqrt{25 - v_r^2}}$

We get $v_r = 3$ km/hr

26. (*a*) To swim across the river for man in the shortest time, one has to swim straight due north. The man's time will not be affected to swimming across the river because the river's velocity is west to east, and there is no component in the north-south.

27. (*a,b,c,d*) $y = \frac{x^2}{2}$

at $t = 0$, $\left.\begin{matrix} x = 0, y = 0 \\ u = 1 \end{matrix}\right\}$ given

$y = \frac{x^2}{2}$

$\frac{dy}{dt} = \frac{1}{2} \cdot 2x\frac{dx}{dt} \Rightarrow v_y = xv_x$

difference w.r.t. time

$a_y = \frac{dx}{dt} \cdot V_x + xa_x$

$a_y = v_x^2 + xa_x$

(*a*) If $a_x = 1$ and particle is at origin $(x = 0, y = 0)$

$a_y = v_x^2 \Rightarrow a_y = 1^2 = 1$

At origin, at $t = 0$ sec

speed = 1 m/s given

(*b*) $a_y = v_x^2 + xa_x$

given in option (*b*), $a_x = 0 \Rightarrow a_y = v_x^2$

If $a_x = 0$, v_x = constant = 1, (all time)

$\Rightarrow a_y = 1^2 = 1$ (all the time)

(*c*) at $t = 0, x = 0$ $v_y = xv_x$

speed = 1

$v_y = 0$

$v_x = 1$

(*d*) $a_y = v_x^2 + xa_x$

$v_y = xv_x$

$a_x = 0$ (given in (*d*) option) $\Rightarrow a_y = v_x^2$

If $a_x = 0$

$\Rightarrow v_x$ = constant initially ($v_x = 1$)

$\Rightarrow a_y = 1^2 = 1$

at $t = 1$ sec

$v_y = 0 + a_y \times t = 1 \times 1 = 1$

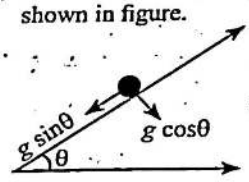
$\tan\theta = \frac{v_y}{v_x} = x$

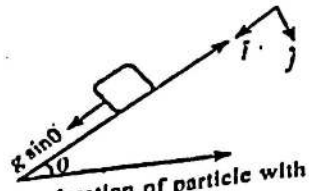
($\theta \rightarrow$ angle with x axis)

$\tan\theta = \frac{v_y}{v_x} = \frac{1}{1} = 1$

$\theta = 45°$

28. (*a*) Accelerations of particle and block are shown in figure.





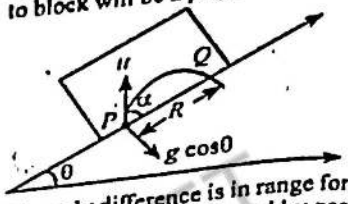
Acceleration of particle with respect to box

= acceleration of particle − acceleration of box

$= (g\sin\theta\hat{i} + g\cos\theta\hat{j}) - (g\sin\theta)\hat{i}$

$= g\cos\theta\hat{j}$

Now, motion of a particle with respect to block will be a projectile as shown.

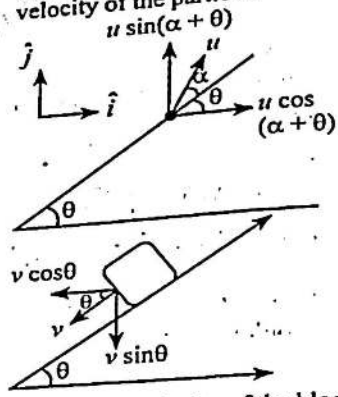


The only difference is in range formula is g and it will be replaced by gcosθ

PQ = Range $(R) = \frac{u^2 \sin 2\alpha}{g\cos\theta}$

(*b*) Horizontal displacement of particle w.r.t. ground is zero.

This implies that initial velocity w.r.t. ground is only vertical or there is no horizontal component of the absolute velocity of the particle.



Let v be the velocity of the block down the plane.

Velocity of particle

$u\cos(\alpha + \theta)\,\hat{i} + u\sin(\alpha + \theta)\,\hat{j}$

Velocity of block $= -v\cos\theta\,\hat{i} - v\sin\theta\,\hat{j}$

$\therefore$ Velocity of particle wrt ground

$[u\cos(\alpha + \theta) - v\cos\theta]\,\hat{i} + [u\sin(\alpha + \theta) - v\sin\theta]\,\hat{j}$

Now, as we said earlier, the horizontal component of absolute velocity is zero.

$u\cos(\alpha + \theta) - v\cos\theta = 0$

$v = \frac{u\cos(\alpha + \theta)}{\cos\theta}$ Velocity of block down the plane.

@FAKE CBSE GRU EDUNET

5 Newton's Laws of Motion

Scan for Sol.

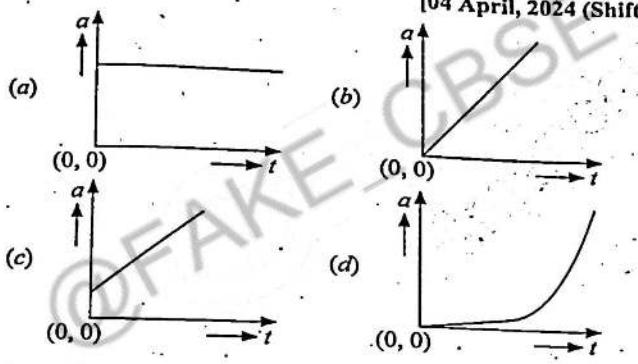
JEE-Main

Laws of Motion

1. A cricket player catches a ball of mass 120 g moving with 25 m/s speed. If the catching process is completed in 0.1 s then the magnitude of force exerted by the ball on the hand of player will be (in SI unit): **[1 Feb, 2024 (Shift-II)]**
(a) 24 (b) 12 (c) 25 (d) 30

2. A body of mass 4 kg experiences two forces $\vec{F}_1 = 5\hat{i} + 8\hat{j} + 7\hat{k}$ and $\vec{F}_2 = 3\hat{i} - 4\hat{j} - 3\hat{k}$.
The acceleration acting on the body is: **[1 Feb, 2024 (Shift-II)]**
(a) $-2\hat{i} - \hat{j} - \hat{k}$ (b) $4\hat{i} + 2\hat{j} + 2\hat{k}$
(c) $2\hat{i} + \hat{j} + \hat{k}$ (d) $2\hat{i} + 3\hat{j} + 3\hat{k}$

3. A wooden block, initially at rest on the ground, is pushed by a force which increases linearly with time t. Which of the following curve best describes acceleration of the block with time: **[04 April, 2024 (Shift-I)]**

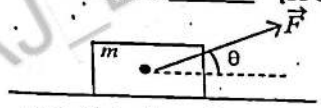


4. A particle moves in x-y plane under the influence of a force $\vec{F}$ such that its linear momentum is $\vec{P}(t) = \hat{i}\cos(kt) - \hat{j}\sin(kt)$. If k is constant, the angle between –F and P– will be: **[05 April, 2024 (Shift-II)]**
(a) $\pi/2$ (b) $\pi/6$ (c) $\pi/4$ (d) $\pi/3$

5. A player caught a cricket ball of mass 150 g moving at a speed of 20 m/s. If the catching process is completed in 0.1 s, the magnitude of force exerted by the ball on the hand of the player is: **[08 April, 2024 (Shift-I)]**
(a) 150 N (b) 3 N (c) 30 N (d) 300 N

6. A spherical body of mass 2 *kg* starting from rest acquires a kinetic energy of 10000 *J* at the end of 5th second. The force acted on the body is _____ *N* **[24 Jan, 2023 (Shift-I)]**

7. An object of mass '*m*' initially at rest on a smooth horizontal surface starts moving under the action of a force $F = 2$ N. In the process of its linear motion, the angle θ (as shown in the figure) between the direction of force and horizontal varies as $\theta = kx$, where *k* is a constant and *x* is the distance covered by the object from its initial position. The expression for kinetic energy of the object will be $E = \frac{n}{k}\sin\theta$. The value of *n* is _____. **[25 Jan, 2023 (Shift-I)]**

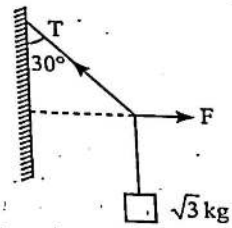


Smooth horizontal surface

8. Force acts for 20 *sec* on a body of mass 20 kg, starting from rest, after which the force ceases and then the body describes 50 *m* in the next 10 *s*. The value of force will be: **[29 Jan, 2023 (Shift-II)]**
(a) 40 N (b) 5 N (c) 20 N (d) 10 N

9. A machine gun of mass 10 kg fires 20 g bullets at the rate of 180 bullets per minute with a speed of 100 ms–1 each. The recoil velocity of the gun is: **[30 Jan, 2023 (Shift-II)]**
(a) 0.02 m/s (b) 2.5 m/s (c) 1.5 m/s (d) 0.6 m/s

10. A block of $\sqrt{3}$ kg is attached to a string whose other end is attached to the wall. An unknown force *F* is applied so that the string makes an angle of 30° with the wall. The tension *T* in the string is: (Given $g = 10\ ms^{-2}$) **[30 Jan, 2023 (Shift-II)]**



(a) 20 N (b) 25 N (c) 10 N (d) 15 N

11. At any instant the velocity of a particle of mass 500 *g* is $\left(2t\hat{i} + 3t^2\hat{j}\right) ms^{-1}$. If the force acting on the particle at $t = 1$s is $\left(\hat{i} + x\hat{j}\right) N$. Then the value of *x* will be: **[08 Apr, 2023 (Shift-1)]**
(a) 3 (b) 4 (c) 6 (d) 2

@FAKE_CBSE_X_@RAJ_EDUCATION

12. Given below are two statements: One is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A): An electric fan continues to rotate for some time after the current is switched off.

Reason (R): Fan continuous to rotate due to inertia of motion.

In the light of above statements, choose the most appropriate answer from the options given below. [10 Apr, 2023 (Shift-II)]

(a) A is correct but R is not correct.
(b) Both A and R are correct and R is the correct explanation of A.
(c) A is not correct but R is correct.
(d) Both A and R are correct but R is not the correct explanation of A.

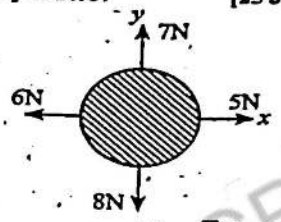
13. Three forces $F_1 = 10N$, $F_2 = 8\ N$, $F_3 = 6\ N$ are acting on a particle of mass 5kg. The forces F_2 and F_3 are applied perpendicular so that particle remains at rest. If the force F_1 is removed, then the acceleration of the particle is: [12 Apr, 2023 (Shift-I)]

(a) $2\ ms^{-2}$ (b) $0.5\ ms^{-2}$
(c) $4.8\ ms^{-2}$ (d) $7\ ms^{-2}$

14. A particle of mass m is moving in the xy-plane such that its velocity at a point (x, y) is given as $\vec{v} = \alpha(y\hat{x} + 2x\hat{y})$, where a is a non-zero constant. What is the force $\vec{F}$ acting on the particle? [JEE Adv, 2023]

(a) $\vec{F} = 2m\alpha^2(x\hat{x} + y\hat{y})$ (b) $\vec{F} = m\alpha^2(y\hat{x} + 2x\hat{y})$
(c) $\vec{F} = 2m\alpha^2(y\hat{x} + x\hat{y})$ (d) $\vec{F} = m\alpha^2(x\hat{x} + 2y\hat{y})$

15. For a free body diagram shown in the figure, the four forces are applied in the 'x' and 'y' directions. What additional force must be applied and at what angle with positive x-axis so that the net acceleration of body is zero? [25 July, 2022 (Shift-II)]



(a) $\sqrt{2}$N, 45° (b) $\sqrt{2}$N, 135°
(c) $\frac{2}{\sqrt{3}}$N, 30° (d) 2N, 45°

16. A bag of sand of mass 9.8 kg is suspended by a rope. A bullet of 200 g travelling with speed 10 ms^{-1} gets embedded in it, then loss of kinetic energy will be: [25 July, 2022 (Shift-II)]

(a) 4.9 J (b) 9.8 J
(c) 14.7 J (d) 19.6 J.

17. A monkey of mass 50 kg climbs on a rope which can withstand the tension (T) of 350 N. If monkey initially climbs down with an acceleration of 4 m/s² and then climbs up with an acceleration of 5 m/s². Choose the correct option
(Take $g = 10\ ms^{-2}$) [26 July, 2022 (Shift-I)]

(a) $T = 700$ N while climbing upward
(b) $T = 350$ N while going downward
(c) Rope will break while climbing upward
(d) Rope will break while going downward

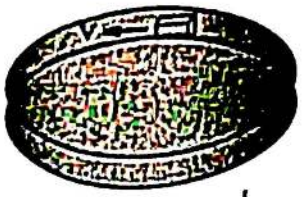
18. The velocity of the bullet becomes one third after it penetrates 4 cm in a wooden block. Assuming that bullet is facing a constant resistance during its motion in the block. The bullet stops completely after travelling at $(4 + x)$ cm inside the block. The value of x is: [27 July, 2022 (Shift-II)]

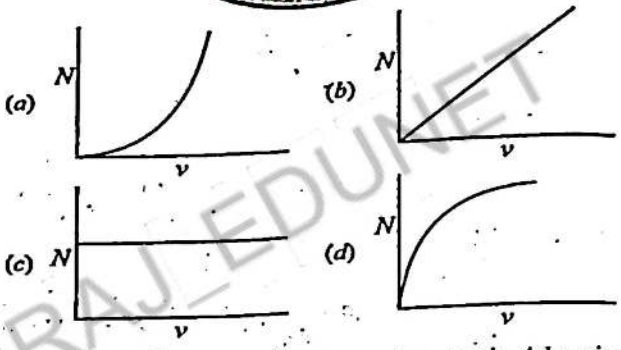
(a) 2.0 (b) 1.0 (c) 0.5 (d) 1.5

19. A balloon has mass of 10 g in air. The air escapes from the balloon at a uniform rate with velocity 4.5 cm/s. If the balloon shrinks in 5 s completely. Then, the average force acting on the balloon will be (in dyne). [28 July, 2022 (Shift-I)]

(a) 3 (b) 9 (c) 12 (d) 18

20. A smooth circular groove has a smooth vertical wall as shown in figure. A block of mass m moves against the wall with a speed v. Which of the following curve represents the correct relation between the normal reaction on the block by the wall (N) and speed of the block (v)? [29 July, 2022 (Shift-I)]





21. A particle is projected with velocity v_0 along x-axis. A damping force is acting on the particle which is proportional to the square of the distance from the origin i.e. $ma = -\alpha x^2$. The distance at which the particle stops: [24 Feb, 2021 (Shift-II)]

(a) $\left(\frac{2v_0}{3\alpha}\right)^{\frac{1}{3}}$ (b) $\left(\frac{3v_0^2}{2\alpha}\right)^{\frac{1}{2}}$
(c) $\left(\frac{2v_0^2}{3\alpha}\right)^{\frac{1}{2}}$ (d) $\left(\frac{3v_0^2 m}{2\alpha}\right)^{1/3}$

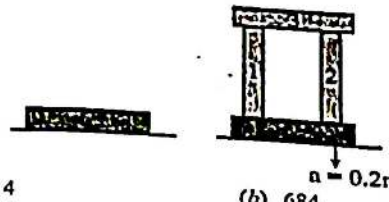
22. Two particles having masses 4 g and 16 g respectively are moving with equal kinetic energies.
The ratio of the magnitudes of their linear momentum is $n : 2$ The value of n will be _____ [25 Feb, 2021 (Shift-II)]

23. A boy pushes a box of mass 2kg with a force $\vec{F} = (20\hat{i} + 10\hat{j})\ N$ on a frictionless surface. If the box was initially at rest, then _____ is displacement along the x-axis after 10 s. [26 Feb, 2021 (Shift-I)]

24. A body of mass 2 kg moves under a force of $(2\hat{i} + 3\hat{j} + 5\hat{k})\ N$. It starts from rest and was at the origin initially. After 4s, its new coordinates are (8, b, 20). The value of b is: (Round off to the Nearest Integer). [16 March, 2021 (Shift-II)]

25. A steel block of 10 kg rests on a horizontal floor as shown. When three iron cylinders are placed on it as shown, the block and cylinders go down with an acceleration 0.2m/s2. The normal reaction R' by the floor if mass of the iron cylinders are equal and of 20kg each, is _____N.
[Take g = 10m/s² and $\mu_s = 0.2$] [20 July, 2021 (Shift-I)]

@PKEDBSE X @RAJ_EDUNET

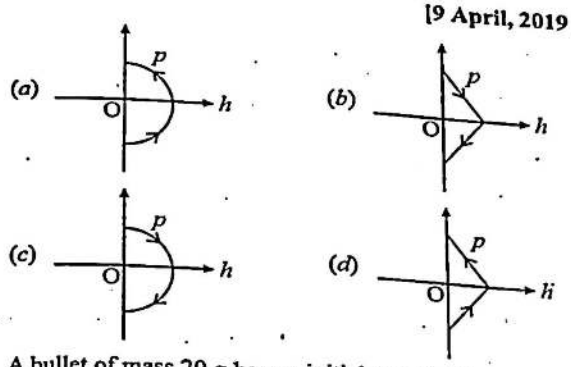


(a) 714 (b) 684
(c) 716 (d) 686

26. A force $\vec{F} = (40\hat{i} + 10\hat{j})N$ acts on a body of mass 5 kg. If the body starts from rest, its position vector $\vec{r}$ at time $t = 10s$, will be:
[25 July, 2021 (Shift-II)]

(a) $(100\hat{i} + 100\hat{j})m$ (b) $(400\hat{i} + 100\hat{j})m$
(c) $(400\hat{i} + 400\hat{j})m$ (d) $(100\hat{i} + 400\hat{j})m$

27. A ball is thrown vertically up (taken as +z-axis) from the ground. The correct momentum height (p-h) diagram is:
[9 April, 2019 (Shift-I)]

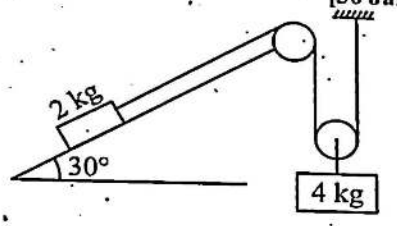


28. A bullet of mass 20 g has an initial speed of 1 ms–1, just before it starts penetrating a mud wall of thickness 20 cm. If the wall offers a mean resistance of 2.5 × 10–2 N, the speed of the bullet after emerging from the other side of the wall is close to
[10 April, 2019 (Shift-II)]

(a) 0.4 ms^{-1} (b) 0.1 ms^{-1} (c) 0.3 ms^{-1} (d) 0.7 ms^{-1}

Impulse, Connected Bodies, Constraint Relations

29. All surfaces shown in figure are assumed to be frictionless and the pulleys and the string are light. The acceleration of the block of mass 2 kg is:
[30 Jan, 2024 (Shift-I)]

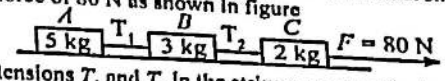


(a) g (b) $\frac{g}{3}$ (c) $\frac{g}{2}$ (d) $\frac{g}{4}$

30. A spherical body of mass 100 g is dropped from a height of 10 m from the ground. After hitting the ground, the body rebounds to a height of 5m. The impulse of force imparted by the ground to the body is given by: (given $g = 9.8$ m/s^2)
[30 Jan, 2024 (Shift-I)]

(a) 4.32 kg ms^{-1} (b) 43.2 kg ms^{-1}
(c) 23.9 kg ms^{-1} (d) 2.39 kg ms^{-1}

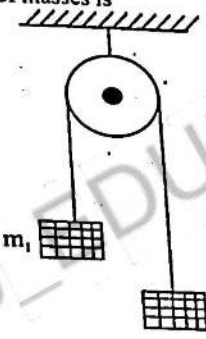
31. Three blocks A, B and C are pulled on a horizontal smooth surface by a force of 80 N as shown in figure



The tensions T_1 and T_2 in the string are respectively:
[30 Jan, 2024 (Shift-II)]

(a) 40N, 64N (b) 60N, 80N
(c) 88N, 96N (d) 80N, 100N

32. A light string passing over a smooth light fixedpulley connects two blocks of masses m1 and m2 .If the acceleration of the system is g/8, then the ratio of masses is
[31 Jan, 2024 (Shift-II)]



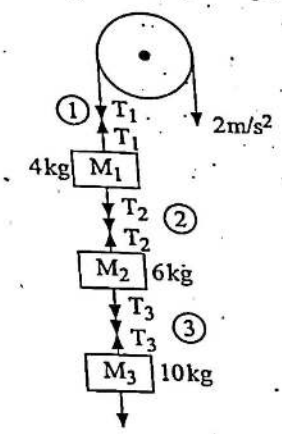
[31 Jan, 2024 (Shift-II)]

(a) $\frac{9}{7}$ (b) $\frac{8}{1}$ (c) $\frac{4}{3}$ (d) $\frac{5}{3}$

33. A wooden block of mass 5kg rests on soft horizontal floor. When an iron cylinder of mass 25 kg is placed on the top of the block, the floor yields and the block and the cylinder together go down with an acceleration of 0.1 ms–2. The action force of the system on the floor is equal to:
[05 April, 2024 (Shift-I)]

(a) 297 N (b) 294 N (c) 291 N (d) 196 N

34. Three blocks M1, M2, M3 having masses 4 kg, 6 kg and 10 kg respectively are hanging from a smooth pully using rope 1, 2 and 3 as shown in figure. The tension in the rope 1, T1 when they are moving upward with acceleration of 2ms–2 is ..... N (if g = 10 m/s2)
[05 April, 2024 (Shift-I)]



JOIN TELEGRAM @RAJ_EDUNET

35. A light string passing over a smooth light pulley connects two blocks of masses m_1 and m_2 (where $m_2 > m_1$). If the acceleration of the system is $\frac{g}{\sqrt{2}}$, then the ratio of the masses $\frac{m_1}{m_2}$ is:

[06 April, 2024 (Shift-I)]

(a) $\frac{\sqrt{2}-1}{\sqrt{2}+1}$ (b) $\frac{1+\sqrt{5}}{\sqrt{5}-1}$

(c) $\frac{1+\sqrt{5}}{\sqrt{2}-1}$ (d) $\frac{\sqrt{3}+1}{\sqrt{2}-1}$

36. A body of weight 200 N is suspended form a tree branch through a chain of mass 10 kg. The branch pulls the chain by a force equal to (if $g = 10\ m/s^2$): [06 April, 2024 (Shift-II)]

(a) 150 N (b) 300 N (c) 200 N (d) 100 N

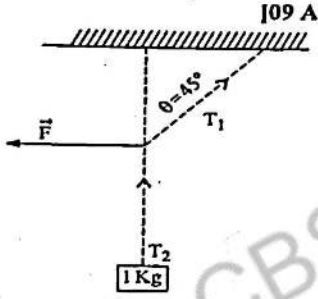
37. A light unstretchable string passing over a smooth light pulley connects two blocks of masses m_1 and m_2. If the acceleration of the system is $\frac{g}{8}$, then the ratio of the masses m_2/m_1 is:

[09 April, 2024 (Shift-I)]

(a) 9 : 7 (b) 4 : 3 (c) 5 : 3 (d) 8 : 1

38. A 1 kg mass is suspended from the ceiling by a rope of length 4m. A horizontal force 'F' is applied at the mid point of the rope so that the rope makes an angle of 45° with respect to the vertical axis as shown in figure. The magnitude of F is:

[09 April, 2024 (Shift-II)]



(a) $\frac{10}{\sqrt{2}}$ N (b) 1 N

(c) $\frac{1}{10\times\sqrt{2}}$ N (d) 10 N

39. Given below are two statements:

Statement-I: An elevator can go up or down with a uniform speed when its weight is balanced with the tension of its cable.

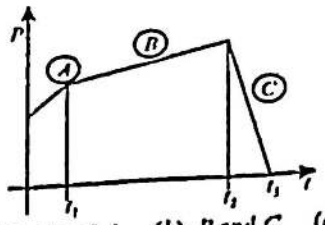
Statement-II: Force exerted by the floor of an elevator on the foot of a person standing on it is more than his/her weight when the elevator goes down with increasing speed.

In the light of the above statements, choose the correct answer from the options given below: [24 Jan, 2023 (Shift-I)]

(a) Both statement-I and statement-II are false
(b) Statement-I is true but Statement-II is false
(c) Both Statement-I and Statement-II are true
(d) Statement-I is false but Statement-II is true

40. The figure represents the momentum time ($P-t$) curve for a particle moving along an axis under the influence of the force. Identify the regions on the graph where the magnitude of the force is maximum and minimum respectively?

If $(t_3 - t_2) < t_1$. [30 Jan, 2023 (Shift-I)]



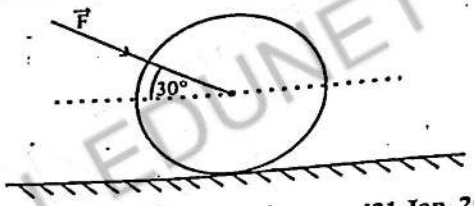
(a) C and A (b) B and C (c) C and B (d) A and B

41. 100 balls each of mass m moving with speed v simultaneously str a wall normally and are reflected back with the same speed. In ti t s. The total force exerted by the balls on the wall is

[31 Jan, 2023 (Shift-

(a) $\frac{100mv}{t}$ (b) $\frac{200mv}{t}$ (c) $200\ mvt$ (d) $\frac{mv}{100t}$

42. As shown in figure, a 70kg garden roller is pushed with a force $\vec{F} = 200\ N$ at an angle of 30° with horizontal. The normal react on the roller is (Given $g = 10\ ms^{-2}$)

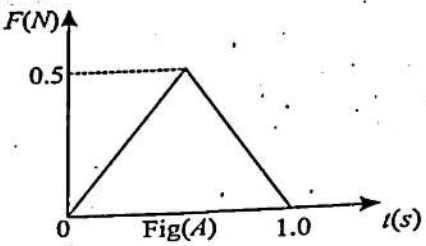


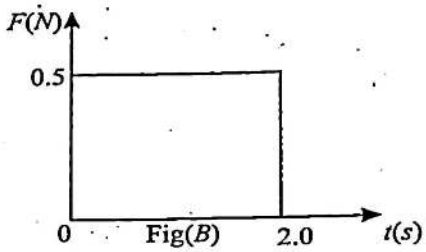
[31 Jan, 2023 (Shift-

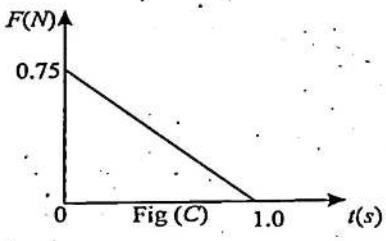
(a) $800\sqrt{2}\ N$ (b) $600\ N$

(c) $800\ N$ (d) $200\sqrt{3}\ N$

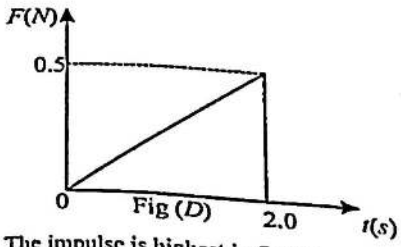
43. Figures (A), (B), (C) and (D) show variation of force with time.







@FAKE_CBSE X @RAJ_EDUNET



The impulse is highest in figure. **[1 Feb, 2023 (Shift-II)]**

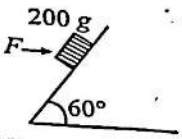
(a) Fig (C) (b) Fig (B) (c) Fig (A) (d) Fig (D)

44. A bullet 10 g leaves the barrel of gun with a velocity of 600 m/s. If the barrel of gun is 50 cm long and mass of gun is 3 kg, then value of impulse supplied to the gun will be **[13 Apr, 2023 (Shift-I)]**

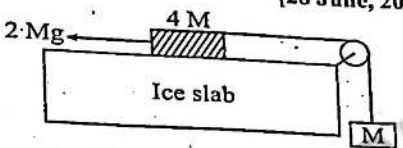
(a) 12 Ns (b) 6 Ns (c) 36 Ns (d) 3 Ns

45. A block of mass 200 g is kept stationary on a smooth inclined plane by applying a minimum horizontal force $F = \sqrt{x}N$ as shown in figure. The value of x = _____.

[25 June, 2022 (Shift-II)]

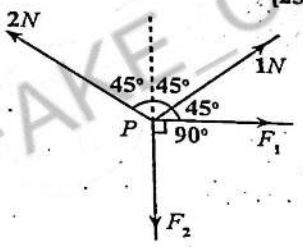


46. A hanging mass M is connected to a four times bigger mass by using a string pulley arrangement, as shown in the figure. The bigger mass is placed on a horizontal ice-slab and being pulled by 2 Mg force. In this situation, tension in the string is x/5 Mg for x = _____. Neglect mass of the string and friction of the block (bigger mass) with ice slab. **[28 June, 2022 (Shift-I)]**



47. Four forces are acting at a point P in equilibrium as shown in figure. The ratio of force F_1 to F_2 is 1: x where x = _____.

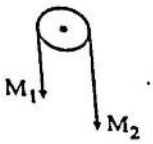
[25 July, 2022 (Shift-I)]



48. Two billiard balls of mass 0.05 kg each moving in opposite directions with 10 ms–1 collide and rebound with the same speed. If the time duration of contact is $t = 0.005$ s. then what is the force exerted on the ball due to each other? **[25 July, 2022 (Shift-II)]**

(a) 100 N (b) 200 N (c) 300 N (d) 400 N

49. Two masses M_1 and M_2 are tied together at the two ends of a light inextensible string that passes over a frictionless pulley. When the mass M_2 is twice that of M_1 the acceleration of the system is a1. When the mass M_2 is thrice that of M_1. The acceleration of system is a_2. The ratio a_1/a_2 will be **[26 July, 2022 (Shift-II)]**



(a) $\frac{1}{3}$ (b) $\frac{2}{3}$

(c) $\frac{3}{2}$ (d) $\frac{1}{2}$

50. A ball of mass 0.15 kg hits the wall with its initial speed of 12 ms^{-1} and bounces back without changing its initial speed. If the force applied by the wall on the ball during the contact is 100 N, calculate the time during of the contact of ball with the wall.

[26 July, 2022 (Shift-II)]

(a) 0.018 s (b) 0.036 s (c) 0.009 s (d) 0.072 s

51. In two different experiments, an object of mass 5 kg moving with a speed of 25 ms^{-1} hits two different walls and comes to rest within (i) 3 second, (ii) 5 seconds, respectively. Choose the correct option out of the following: **[28 July, 2022 (Shift-I)]**

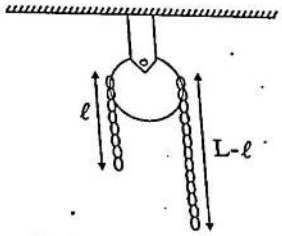
(a) Impulse and average force acting on the object will be same for both the cases.

(b) Impulse will be same for both the cases but the average force will be different.

(c) Average force will be same for both the cases but the impulse will be different.

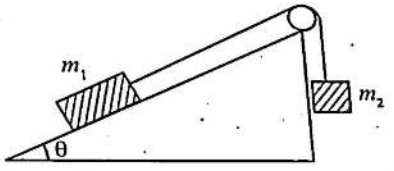
(d) Average force and impulse will be different for both the cases.

52. A uniform metal chain of mass m and length 'L' passes over a massless and frictionless pulley. It is released from rest with a part of its length 'ℓ' is hanging on one side and rest of its length '$L-\ell$' is hanging on the other side of the pully. At a certain point of time, when $\ell = \frac{L}{x}$ the acceleration of the chain is $\frac{g}{2}$. The value of x is _____. **[28 July, 2022 (Shift-II)]**



(a) 6 (b) 2 (c) 1.5 (d) 4

53. Two bodies of masses $m_1 = 5$kg and $m_2 = 3$kg are connected by a light string going over a smooth light pulley on a smooth inclined plane as shown in the figure. The system is at rest. The force exerted by the inclined plane on the body of mass m_1 will be: [Take $g = 10$ ms^{-2}] **[29 July, 2022 (Shift-II)]**



(a) 30 N (b) 40 N (c) 50 N (d) 60 N

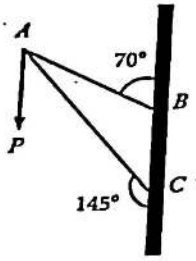
@FAKE_CASE_X@_EDUR

54. An inclined plane is bent in such a way that the vertical cross- section is given by $y = \frac{x^3}{4}$ where y is in vertical and x in horizontal direction. If the upper surface of this curved plane is rough with coefficient of friction $\mu = 0.5$, the maximum height in cm at which a stationary block will not skip downward is _____ cm.
[24 Feb, 2021 (Shift-I)]

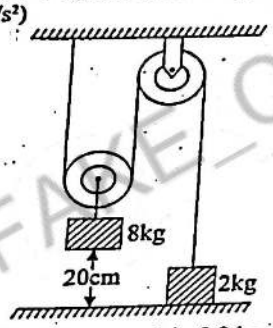
55. A person standing on a balance inside a stationary lift measures 60 kg. The weight of that person if the lift descends with uniform downward acceleration of 1.8 m/s² will be _____ N. [$g = 10$ m s^{-2}]
[26 Feb, 2021 (Shift-I)]

56. Consider a frame that is made up of two thin massless rods AB and AC as shown in the figure. A vertical force $\vec{P}$ of magnitude 100N is applied at point A of the frame. Suppose the force is $\vec{P}$ resolved parallel to the arms AB and AC of the frame. The magnitude of the resolved component along the arm AC is xN.
[16 March, 2021 (Shift-I)]

The value of x, to the nearest integer, is _____.
[Given: sin(35°) = 0.573, cos(35°) = 0.819
sin(110°) = 0.939, cos(110°) = –0.342]

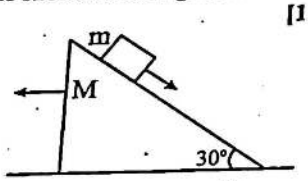


57. The boxes of masses 2 kg and 8 kg are connected by a massless string passing over smooth pulleys. Calculate the time taken by box of mass 8 kg to strike the ground starting from rest. (use $g = 10$ m/s²)
[27 Aug, 2021 (Shift-II)]



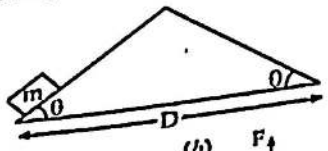
(a) 0.25 s (b) 0.4 s (c) 0.34 s (d) 0.2 s

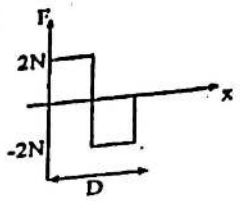
58. A block of mass m slides on the wooden wedge, which in turn slides backward on the horizontal surface. The acceleration of the block with respect to the wedge is: Given $m = 8$ kg, $M = 16$ kg Assume all the surfaces shown in the figure to be frictionless.
[1 Sept, 2021 (Shift-II)]

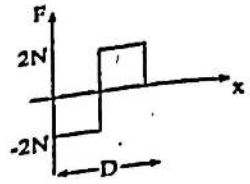


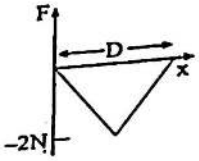
(a) $\frac{6}{5}g$ (b) $\frac{3}{5}g$ (c) $\frac{2}{3}g$ (d) $\frac{4}{3}g$

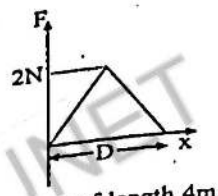
59. An object of mass 'm' is being moved with a constant velocity under the action of an applied force of $2N$ along a frictionless surface with following surface profile. The correct applied force vs distance graph will be:
[1 Sept, 2021 (Shift-II)]



(a)


(b)


(c)


(d)


60. A mass of 10 kg is suspended by a rope of length 4m, from the ceiling. A force F is applied horizontally at the mid-point of the rope such that the top half of the rope makes an angle of 45° with the vertical. Then F equals
(Take $g = 10$ ms^{-2} and the rope to be massless)
[7 Jan, 2020 (Shift-II)]

(a) 75 N (b) 90 N (c) 100 N (d) 70 N

61. A small ball of mass m is thrown upward with velocity u from the ground. The ball experiences a resistive force mkv², where v is its speed. The maximum height attained by the ball is
[04 Sep, 2020 (Shift-II)]

(a) $\frac{1}{2K}\tan^{-1}\frac{ku^2}{g}$ (b) $\frac{1}{K}\ln\left(1+\frac{ku^2}{2g}\right)$

(c) $\frac{1}{2K}\ln\left(1+\frac{ku^2}{g}\right)$ (d) $\frac{1}{K}\tan^{-1}\frac{ku^2}{2g}$

62. A mass of 10 kg is suspended vertically by a rope from the roof. When a horizontal force is applied on the rope at some point, the rope deviated at an 45° at the roof point. If the suspended mass is at equilibrium, the magnitude of the force applied is ($g = 10$ ms
[9 Jan, 2019 (Shift-I

(a) 200 N (b) 140 N (c) 70 N (d) 100 N

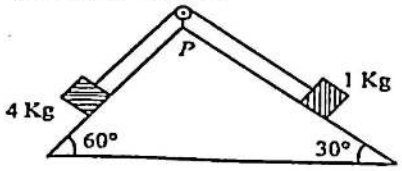
63. A particle of mass m is initially at rest at the origin. It is subjected to a force and starts moving along the x-axis. Its kinetic energy changes with time as dK/dt = γt, where γ is a positive constant of appropriate dimensions. Which of the following statements is (are true?
[JEE Adv, 201

(a) The force applied on the particle is constant
(b) The speed of the particle is proportional to time
(c) The distance of the particle from the origin increases linear with time.
(d) The force is conservative

@FAKE_CBSE_@RAJ_TIWARI_NET

Constraint Relation, Dynamics of Multi System, Springs

64. As per given figure, a weightless pulley P is attached on a double inclined frictionless surface. The tension in the string (massless) will be (if $g = 10 m/s^2$) [24 Jan, 2023 (Shift-I)]



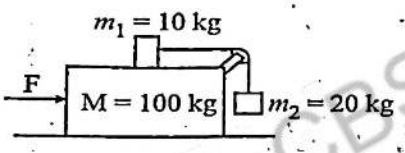
(a) $(4\sqrt{3}+1)N$ (b) $4(\sqrt{3}+1)N$

(c) $4(\sqrt{3}-1)N$ (d) $(4\sqrt{3}-1)N$

65. A block of mass M placed inside a box descends vertically with acceleration 'a'. The block exerts a force equal to one-fourth of its weight on the floor of the box. The value of 'a' will be: [29 June, 2022 (Shift-II)]

(a) $g/4$ (b) $g/2$ (c) $3g/4$ (d) g

66. Three masses $M = 100$ kg, $m_1 = 10$ kg and $m_2 = 20$ kg are arranged in a system as shown in figure. All the surfaces are frictionless and strings are inextensible and weightless. The pulleys are also weightless and frictionless. A force F is applied on the system so that the mass m_2 moves upward with an acceleration of 2 ms^{-2}. The value of F is
(Take $g = 10$ ms^{-2}) [26 July, 2022 (Shift-I)]



(a) 3360 N (b) 3380 N (c) 3120 N (d) 3240 N

67. A car is moving on a plane inclined at 30° to the horizontal with an acceleration of 10 ms^{-2} parallel to the plane upward. A bob is suspended by a string from the roof of the car. The angle in degrees which the string makes with the vertical is_____.
(Take $g = 10$ ms^{-2}) [31 Aug, 2021 (Shift-I)]

68. A spring whose unstretched length is l has a force constant k. The spring is cut into two pieces of unstretched lengths l_1 and l_2 where, $l_1 = n_1^2$ and n is an integer. The ratio k^1/k^2 of the corresponding force constants, k_1 and k_2 will be [12 April, 2019 (Shift-II)]

(a) $\frac{1}{n^2}$ (b) n^2 (c) $\frac{1}{n}$ (d) n

Static Friction & Kinetic Friction

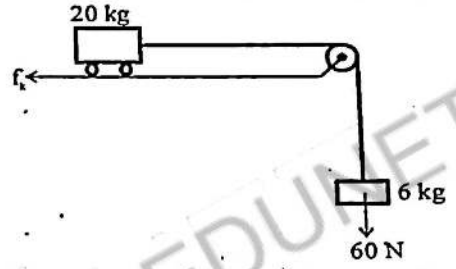
69. Given below are two statements: [27 JAN, 2024 (Shift-II)]
Statement-I: The limiting force of static friction depends on the area of contact and independent of materials.

[27 JAN, 2024 (Shift-II)]
Statement-II: The limiting force of kinetic friction is independent of the area of contact and depends on materials.

[27 JAN, 2024 (Shift-II)]
In the light of the above statements, choose the most appropriate answer from the options given below: [27 JAN, 2024 (Shift-II)]

(a) Statement-I is correct but Statement-II is incorrect
(b) Statement-I is incorrect but Statement-II is correct
(c) Both Statement-I and Statement-II are incorrect
(d) Both Statement-I and Statement-II are correct

70. Consider a block and trolley system as shown in figure. If the coefficient of kinetic friction between the trolley and the surface is 0.04, the acceleration of the system in ms^{-2} is:
(Consider that the string is massless and unstretchable and the pulley is also massless and frictionless): [1 Feb, 2024 (Shift-I)]



(a) 3 (b) 4 (c) 2 (d) 1.2

71. The vehicles carrying inflammable fluids usually have metallic chains touching the ground: [05 April, 2024 (Shift-II)]
(a) To conduct excess charge due to air friction to ground and prevent sparking.
(b) To alert other vehicles.
(c) To protect tyres from catching dirt from ground.
(d) It is a custom.

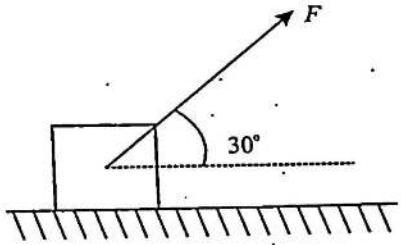
72. A body of mass 10 kg is moving with an initial speed of 20 m/s. The body stops after 5 s due to friction between body and the floor. The value of the coefficient of friction is:
(Take acceleration due to gravity $g = 10$ ms^{-2})
[31 Jan, 2023 (Shift-II)]

(a) 0.2 (b) 0.3 (c) 0.5 (d) 0.4

73. A block of mass 5 kg is placed at rest on a table of rough surface. Now, if a force of 30 N is applied in the direction parallel to surface of the table, the block slides through a distance of 50 m in an interval of time 10 s. Coefficient of kinetic friction is (given, $g = 10$ ms^{-2}): [1 Feb, 2023 (Shift-1)]

(a) 0.60 (b) 0.75 (c) 0.50 (d) 0.25

74. As shown in the figure a block of mass 10 kg lying on a horizontal surface is pulled by a force F acting at an angle 30°, with horizontal. For $\mu_s = 0.25$, the block will just start to move for the value of F:
[Given g = 10ms^{-2}] [1 Feb, 2023 (Shift-II)]



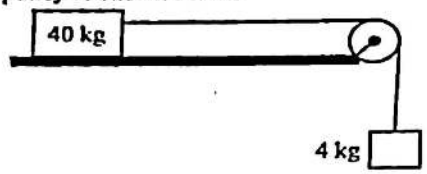
(a) 33.3 N (b) 25.2 N (c) 20 N (d) 35.7 N

@TAKE_CBSE_X@TELEGRAM.NET

75. A bullet of mass 0.1 *kg* moving horizontally with speed 400 ms^{-1} hits a wooden block of mass 3.9 *kg* kept on a horizontal rough surface. The bullet gets embedded into the block and moves 20 *m* before coming to rest. The coefficient of friction between the block and the surface is
(Given g = 10ms^{-2}) [8 April, 2023 (Shift-II)]
(*a*) 0.50 (*b*) 0.90 (*c*) 0.65 (*d*) 0.25

76. A uniform chain of 6 m length is placed on a table such that a part of its length is hanging over the edge of the table. The system is at rest. The co-efficient of static friction between the chain and the surface of the table is 0.5, the maximum length of the chain hanging from the table is _____m. [25 June, 2022 (Shift-I)]

77. A block of mass 40 kg slides over a surface, when a mass of 4 kg is suspended through an inextensible massless string passing over frictionless pulley as shown below.

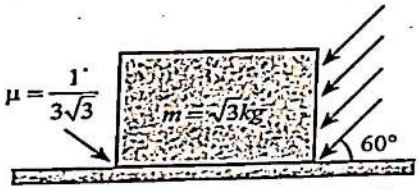


The coefficient of kinetic friction between the surface and block is 0.02. The acceleration of block is.
(given g = 10 ms^{-2}) [29 June, 2022 (Shift-II)]
(*a*) 1 ms^{-2} (*b*) 1/5 ms^{-2} (*c*) 4/5 ms^{-2} (*d*) 8/11 ms^{-2}

78. A bag is gently dropped on a conveyor belt moving at a speed of 2 m/s. The coefficient of friction between the conveyor belt and bag is 0.4. Initially, the bag slips on the belt before it stops due to friction. The distance travelled by the bag on the belt during slipping motion is:
[Take g = 10 m/s^{-2}] [27 July, 2022 (Shift-I)]
(*a*) 2 m (*b*) 0.5 m (*c*) 3.2 m (*d*) 0.8 m

79. The coefficient of static friction between a wooden block of mass 0.5 kg and a vertical rough wall is 0.2. The magnitude of horizontal force that should be applied on the block to keep it adhere to the wall be _____N. [*g* = 10 ms–2] [24 Feb, 2021 (Shift-I)]

80. As shown in the figure, a block of mass $\sqrt{3}\,kg$ is kept on a horizontal rough surface of coefficient of friction $\frac{1}{3\sqrt{3}}$. The critical force to be applied on the vertical surface as shown at an angle 60° with horizontal such that it does not move, will be 3*x*. The value of *x* will be [26 Feb, 2021 (Shift-I)]



$$\left[g = 10\,m/s^2; \sin 60^\circ = \frac{\sqrt{3}}{2}; \cos 60^\circ = \frac{1}{2}\right]$$

81. A block of mass m slides along a floor while a force of magnitude F is applied to it at an angle θ as shown in figure. The coefficient of kinetic is μ_K. Then, the block's acceleration 'a' is given by:
(g is acceleration due to gravity) [16 March, 2021 (Shift-I)]

(*a*) $\frac{F}{m}\cos\theta + \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

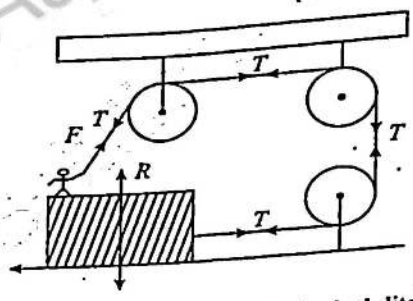
(*b*) $\frac{F}{m}\cos\theta + \mu_K\left(g + \frac{F}{m}\sin\theta\right)$

(*c*) $\frac{F}{m}\cos\theta - \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

(*d*) $-\frac{F}{m}\cos\theta - \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

82. A body of mass 1 kg rests on a horizontal floor with which it has a coefficient of static friction $\frac{1}{\sqrt{3}}$. It is desired to make the body move by applying the minimum possible force F (in N). The value of F will be _____ (Round off to the Nearest Integer)
[Take g = 10 ms^{-2}] [17 March, 2021 (Shift-II)]

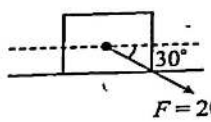
83. A boy of mass 4 kg is standing on a piece of wood having mass 5 kg. If the coefficient of friction between the wood and the floor is 0.5, what is the maximum force that the boy can exert on the rope so that the piece of wood does not move from its place is _____ (in N). (Round off to the Nearest Integer) [Take g = 10 ms–2]
[17 March, 2021 (Shift-II)]



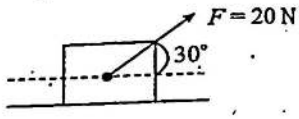
84. An insect is at the bottom of a hemispherical ditch of radius 1 m. It crawls up the ditch but starts slipping after it is at height h from the bottom. If the coefficient of friction between the ground and the insect is 0.75, then h is (g = 10 ms–2) [6 Sep, 2020 (Shift-I)]
(*a*) 0.45 m (*b*) 0.80 m
(*c*) 0.20 m (*d*) 0.60 m

85. A block of mass 5 kg is (i) pushed in case (a) and (ii) pulled in case (b). by a force F = 20 N. Making an angle of 30° with the horizontal, as shown in the figures. The coefficient of friction between the block and floor is m = 0.2. The difference between the accelerations of the block, in case (b) and case (a) will be: (g = 10 ms^{-2})
[12 April, 2019 (Shift-II)]

(*a*)



(*b*)



(*a*) 0 ms^{-2} (*b*) 0.8 ms^{-2} (*c*) 0.4 ms^{-2} (*d*) 3.2 ms^{-2}

@FAKE_OFFICIAL @RAS_EDUMENT

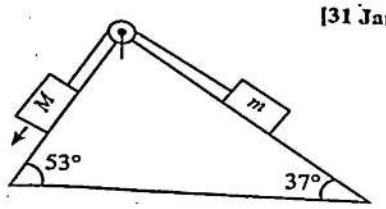
Two block & Inclined Plane Problems

86. A block of mass m is placed on a surface having vertical cross section given by $y = x^2/4$. If coefficient of friction is 0.5, the maximum height above the ground at which block can be placed without slipping is: **[30 Jan, 2024 (Shift-II)]**

(a) 1/4 m (b) 1/2 m (c) 1/6 m (d) 1/3 m

87. In the given arrangement of a doubly inclined plane two blocks of masses M and m are placed. The blocks are connected by a light string passing over an ideal pulley as shown. The coefficient of friction between the surface of the plane and the blocks is 0.25. The value of m, for which $M = 10$ kg will move down with an acceleration of 2 m/s², is: (take g = 10 m/s² and tan 37° = 3/4)

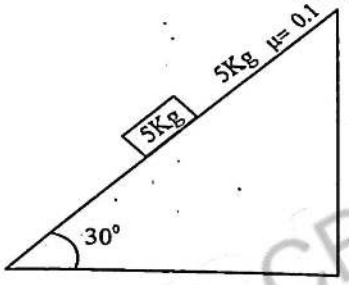
[31 Jan, 2024 (Shift-I)]



[31 Jan, 2024 (Shift-I)]

(a) 9 kg (b) 4.5 kg (c) 6.5 kg (d) 2.25 kg

88. A block of mass 5 kg is placed on a rough inclined surface as shown in the figure. **[31 Jan, 2024 (Shift-II)]**



[31 Jan, 2024 (Shift-II)]

If $\overrightarrow{F_1}$ is the force required to just move the block up the inclined plane and $\overrightarrow{F_2}$ is the force required to just prevent the block from sliding down, then the value of $|\overrightarrow{F_1}| - |\overrightarrow{F_2}|$ is: [Use g = 10m/s²]

(a) $25\sqrt{3}N$ (b) $50\sqrt{3}N$ (c) $\frac{5\sqrt{3}}{2}N$ (d) 10 N

89. A 2 kg brick begins to slide over a surface which is inclined at an angle of 45° with respect to horizontal axis. The co-efficient of static friction between their surfaces is: **[04 April, 2024 (Shift-II)]**

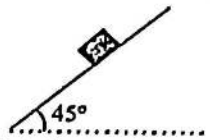
(a) 1 (b) $\frac{1}{\sqrt{3}}$ (c) 0.5 (d) 1.7

90. A given object takes n times the time to slide down 45° rough inclined plane as it takes the time to slide down an identical perfectly smooth 45° inclined plane. The coefficient of kinetic friction between the object and the surface of inclined plane is:

[08 April, 2024 (Shift-II)]

(a) $1-\frac{1}{n^2}$ (b) $1-n^2$ (c) $\sqrt{1-\frac{1}{n^2}}$ (d) $\sqrt{1-n^2}$

91. Consider a block kept on an inclined plane (inclined at 45°) as shown in the figure. If the force required to just push it up the incline is 2 times the force required to just prevent it from sliding down, the coefficient of friction between the block and inclined plane (μ) is equal to: **[25 Jan, 2023 (Shift-II)]**



(a) 0.33 (b) 0.60 (c) 0.25 (d) 0.50

92. A block of mass m slides down an inclined plane inclined at angle 30° with an acceleration $\frac{g}{4}$. The value of coefficient of kinetic friction will be: **[29 Jan, 2023 (Shift-I)]**

(a) $\frac{2\sqrt{3}+1}{2}$ (b) $\frac{1}{2\sqrt{3}}$ (c) $\frac{\sqrt{3}}{2}$ (d) $\frac{2\sqrt{3}-1}{2}$

93. The time taken by an object to slide down a 45° rough inclined plane is n times as it takes to slide down a perfectly smooth 45° inclined plane. The coefficient of kinetic friction between the object and the incline plane is **[29 Jan, 2023 (Shift-II)]**

(a) $\sqrt{\frac{1}{1-n^2}}$ (b) $\sqrt{1-\frac{1}{n^2}}$ (c) $1+\frac{1}{n^2}$ (d) $1-\frac{1}{n^2}$

94. A child of mass 5kg is going round a merry-go-round that makes 1 rotation in 3.14 s. The radius of the merry-go-round is 2 m. The centrifugal force on the child will be **[6 April 2023 (Shift-II)]**

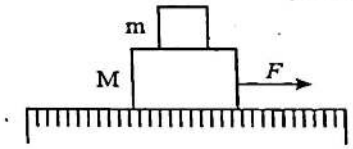
(a) 80 N (b) 50 N (c) 100 N (d) 40 N

95. A block of mass 10 kg, starts sliding on a surface with an initial velocity of 9.8 ms^{-1}. The coefficient of friction between the surface and block is 0.5. The distance covered by the block before coming to rest is:

[Used $g = 9.8\ ms^{-2}$] **[24 June, 2022 (Shift-I)]**

(a) 4.9 m (b) 9.8 m (c) 12.5 m (d) 19.6 m

96. A system of two blocks of masses m = 2 kg and m = 8 kg is placed on a smooth table as shown in figure. The coefficient of static friction between two blocks is 0.5. The maximum horizontal force F that can be applied to the block of mass M so that the blocks move together will be: **[27 June, 2022 (Shift-I)]**



(a) 9.8 N (b) 39.2 N (c) 49 N (d) 78.4 N

97. A block of mass M slides down on a rough inclined plane with constant velocity. The angle made by the incline plane with horizontal is θ. The magnitude of the contact force will be:

[27 July, 2022 (Shift-II)]

(a) Mg (b) $Mg\cos\theta$

(c) $\sqrt{Mg\sin\theta + Mg\cos\theta}$ (d) $Mg\sin\theta\sqrt{1+\mu}$

98. A block 'A' takes 2 s to slide down a frictionless incline of 30° and length 'ℓ', kept inside a lift going up with uniform velocity 'v'. If the incline is changed to 45°, the time taken by the block, to slide down the incline, will be approximately: [27 July, 2022 (Shift-II)]

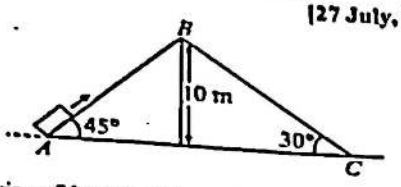
(a) 2.66 s (b) 0.83 s (c) 1.68 s (d) 0.70 s

@FIKE_CBSE_X @RAJEDUNET

99. Two inclined planes are placed as shown in figure. A block is projected from the point A of inclined plane AB along its surface with velocity just sufficient to carry it to the top Point B at a height 10 m. After reaching the point B the block slide down on inclined plane BC. Time it takes to reach to the point C from point A is $t\left(\sqrt{2}+1\right)s$.

The value of t is _____ (use g = 10 m/s2)

[27 July, 2022 (Shift-II)]

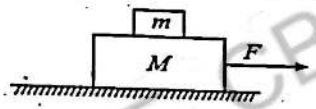


100. A metal wire of length 0.5m and cross-sectional area $10^{-4}m^2$ has breaking stress $5 \times 10^8\ Nm^{-2}$. A block of 10 kg is attached at one of the string and is rotating in a horizontal circle. The maximum linear velocity of block will be _____ ms^{-1}. [29 July, 2022 (Shift-II)]

101. A block of 200 g mass moves with a uniform speed in a horizontal circular groove, with vertical side walls of radius 20cm. If the block takes 40 s to complete one round, the normal force by the side walls of the groove is: [16 March, 2021 (Shift-I)]

(a) 6.28×10^{-3}N (b) 0.0314 N
(c) 9.859×10^{-2}N (d) 9.859×10^{-4}N

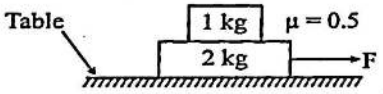
102. Two blocks (m = 0.5 kg and M = 4.5 kg) are arranged on a horizontal frictionless table as shown in figure. The coefficient of static friction between the two blocks is $\frac{3}{7}$. Then the maximum horizontal force that can be applied on the larger block so that the blocks move together is _____ N. (Round off to the Nearest Integer)
[Take g as 9.8 ms^{-2}] [17 March, 2021 (Shift-I)]



103. A body of mass 'm' is launched up on a rough inclined plane making an angle of 30° with the horizontal. The coefficient of friction between the body and plane is $\frac{\sqrt{x}}{5}$ if the time of ascent is half of the time of descent. The value of x is _____.

[20 July, 2021 (Shift-II)]

104. The coefficient of static friction between two blocks is 0.5 and the table is smooth. The maximum horizontal force that can be applied to move the blocks together is _____ N. (take g = 10 ms^{-2}) [26 Aug, 2021 (Shift-II)]



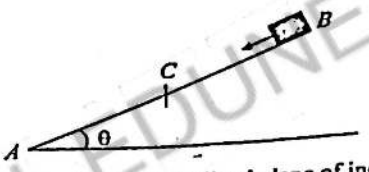
105. A huge circular arc of length 4.4 ly subtends an angle '4s' at the centre of the circle. How long it would take for a body to complete 4 revolution if its speed is 8 AU per second?
Given: 1 ly = 9.46×10^{15} m [27 Aug, 2021 (Shift-I)]
1 AU = 1.5×10^{11} m

(a) 4.5×10^{16} s (b) 4.1×10^{4} s
(c) 3.5×10^{4} s (d) 7.2×10^{6} s

106. When a body slides down from rest along a smooth inclined plane making an angle of 30° with the horizontal, it takes time T. When the same body slides down from the rest along a rough inclined plane making the same angle and through the same distance, it takes time αT, where α is a constant greater than 1. The co-efficient of friction between the body and the rough plane is $\frac{1}{\sqrt{x}}\left(\frac{\alpha^2-1}{\alpha^2}\right)$ where x = _____. [1 Sep, 2021 (Shift-II)]

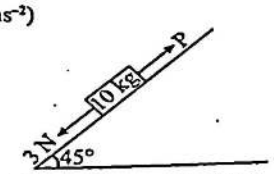
107. A small block starts slipping down from a point B on an inclined plane AB, which is making an angle θ with the horizontal section. BC is smooth and the remaining section CA is rough with a coefficient of friction μ. It is found that the block comes to rest as it reaches the bottom (point A) of the inclined plane. If $BC = 2AC$, the coefficient of friction is given by $\mu = k\tan\theta$. The value of k is _____.

[2 Sep, 2020 (Shift-I)]



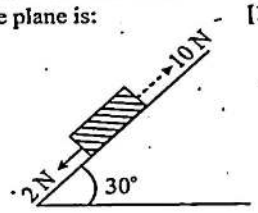
108. A block starts moving up an inclined plane of inclination 30° with an initial velocity of v_0. It comes back to its initial position with velocity $\frac{v_0}{2}$. The value of the coefficient of kinetic friction between the block and the inclined plane is close to $\frac{I}{1000}$. The nearest integer to I is _____. [3 Sep, 2020 (Shift-II)]

109. A block of mass 10 kg is kept on a rough inclined plane as shown in the figure. A force of 3 N is applied on the block. The coefficient of static friction between the plane and the block is 0.6. What should be the minimum value of force P, such that the block does not move downward? (Take g = 10 ms^{-2}) [9 Jan, 2019 (Shift-I)]



(a) 32 N (b) 18 N (c) 23 N (d) 25 N

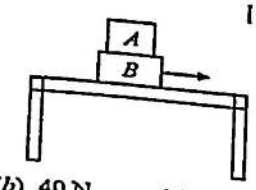
110. A block kept on a rough inclined plane, as shown in the figure, remains at rest up-to a maximum force 2 N down the inclined plane. The maximum external force up the inclined plane that does not move the block is 10 N. The coefficient of static friction between the block and the plane is: [12 Jan, 2019 (Shift-II)]



(a) $\frac{\sqrt{3}}{2}$ (b) $\frac{\sqrt{3}}{4}$ (c) $\frac{1}{2}$ (d) $\frac{2}{3}$

@FREE CBSE @RAJEDUNET

111. Two blocks A and B of masses $m_A = 1$ kg and $m_B = 3$ kg are kept on the table as shown in figure. The coefficient of friction between A and B is 0.2 and between B and the surface of the table is also 0.2. The maximum force F that can be applied on horizontally, so that the block A does not slide over the block B is: (Take $g = 10$ m/s²) [10 April, 2019 (Shift-II)]



(a) 16 N (b) 40 N (c) 12 N (d) 8 N

Dynamics of Circular Motion, Centripetal Force.

112. A train is moving with a speed of 12 m/s on rails which are 1.5 m apart. To negotiate a curve radius 400 m, the height by which the outer rail should be raised with respect to the inner rail is (Given, $g = 10$ m/s²): [27 Jan, 2024 (Shift-I)]
(a) 6.0 cm (b) 5.4 cm (c) 4.8 cm (d) 4.2 cm

113. A coin is placed on a disc. The coefficient of friction between the coin and the disc is μ. If the distance of the coin from the center of the disc is r, the maximum angular velocity which can be given to the disc, so that the coin does not slip away, is: [31 Jan, 2024 (Shift-I)]
(a) $\frac{\mu g}{r}$ (b) $\sqrt{\frac{r}{\mu g}}$ (c) $\sqrt{\frac{\mu g}{r}}$ (d) $\frac{u}{\sqrt{\mu g}}$

114. A ball of mass 0.5 kg is attached to a string of length 50 cm. The ball is rotated on a horizontal circular path about its vertical axis. The maximum tension that the string can bear is 400 N. The maximum possible value of angular velocity of the ball in rad/s is,: [1 Feb, 2024 (Shift-I)]
(a) 1600 (b) 40 (c) 1000 (d) 20

115. A man carrying a monkey on his shoulder does cycling smoothly on a circular track of radius 9m and completes 120 revolutions in 3 minutes. The magnitude of centripetal acceleration of monkey is (in m/s2): [05 April, 2024 (Shift-II)]
(a) zero (b) $16\pi^2$ ms^{-2}
(c) $4\pi^2$ ms^{-2} (d) $57600\pi^2$ ms^{-2}

116. A car of 800 kg is taking turn on a banked road of radius 300 m and angle of banking 30°. If coefficient of static friction is 0.2 then the maximum speed with which car can negotiate the turn safely: ($g = 10$ m/s², $3 = 1.73$) [06 April, 2024 (Shift-II)]
(a) 70.4 m/s (b) 51.4 m/s (c) 264 m/s (d) 102.8 m/s

117. A body of mass 200 *g* is tied to a spring of spring constant 12.5 *N/m*, while the other end of spring is fixed at point *O*. If the body moves about *O* in a circular path on a smooth horizontal surface with constant angular speed 5 *rad/s*, then the ratio of extension in the spring to its natural length will be: [24 Jan, 2023 (Shift-II)]
(a) 1 : 2 (b) 1 : 1
(c) 2 : 3 (d) 2 : 5

118. A car is moving with a constant speed of 20 m/s in a circular horizontal track of radius 40 m. A bob is suspended from the roof of the car by a massless string. The angle made by the string with the vertical will be: (Take $g = 10$ m/s²) [25 Jan, 2023 (Shift-I)]
(a) $\frac{\pi}{6}$ (b) $\frac{\pi}{2}$
(c) $\frac{\pi}{4}$ (d) $\frac{\pi}{3}$

119. A car is moving on a horizontal curved road with radius 50*m*. The approximate maximum speed of car will be, if friction coefficient between tyres and road is 0.34. [Take $g = 10\ ms^{-2}$] [29 Jan, 2023 (Shift-I)]
(a) 3.4 ms^{-1} (b) 22.4 ms^{-1} (c) 13 ms^{-1} (d) 17 ms^{-1}

120. A small block of mass 100 g is tied to a spring of spring constant 7.5 N/m and length 20 cm. The other end of spring is fixed at a particular point A. If the block moves in a circular path on a smooth horizontal surface with constant angular velocity 5 rad/s about point A, then tension in the spring is [6 April, 2023 (Shift-I)]
(a) 1.5 N (b) 0.75 N (c) 0.25 N (d) 0.50 N

121. A coin placed on a rotating table just slips when it is placed at a distance of 1 cm from the center. If the angular velocity of the table in halved, it will just slip when placed at a distance of from the centre: [11 April, 2023 (Shift-I)]
(a) 2 cm (b) 1 cm (c) 8 cm (d) 4 cm

122. A vehicle of mass 200 kg is moving along a levelled curved road of radius 70 m with angular velocity of 0.2 rad/s. The centripetal force acting on the vehicle is: [13 April, 2023 (Shift-II)]
(a) 560 *N* (b) 2800 *N* (c) 14 *N* (d) 2240 *N*

123. A boy ties a stone of mass 100 g to the end of 2 m long string and whirls it around in a horizontal plane. The string can withstand the maximum tension of 80 N. If the maximum speed with which the stone can revolve is $\frac{K}{\pi}$ rev. /min. The value of *K* is:
(Assume the string is massless and unstretchable)
[24 June, 2022 (Shift-I)]
(a) 400 (b) 300 (c) 600 (d) 800

124. A boy ties a stone of mass 100 g to the end of 2 m long string and whirls it around in a horizontal plane. The string can withstand the maximum tension of 80 N. If the maximum speed with which the stone can revolve is $\frac{K}{\pi}$ rev. /min. The value of *K* is:
(Assume the string is massless and unstretchable)
[24 June, 2022 (Shift-I)]
(a) 400 (b) 300 (c) 600 (d) 800

125. A curved in a level road has a radius 75 m. The maximum speed of a car turning this curved road can be 30 m/s without skidding. If radius of curved road is changed to 48m and the coefficient of friction between the tyres and the road remains same, then maximum allowed speed would be _____m/s. [25 June, 2022 (Shift-II)]

126. A disc with a flat small bottom beaker placed on it at a distance R from its center is revolving about an axis passing through the center and perpendicular to its plane with an angular velocity ω. The coefficient of static friction between the bottom of the beaker and the surface of the disc is μ. The beaker will revolve with the disc if: [25 June, 2022 (Shift-II)]

@NKF_CBSE_X@NJ_EDUMEDIA

(a) $R \le \frac{\mu g}{2\omega^2}$ (b) $R \le \frac{\mu g}{\omega^2}$

(c) $R \ge \frac{\mu g}{2\omega^2}$ (d) $R \ge \frac{\mu g}{\omega^2}$

127. One end of a massless spring of spring constant k and natural length l0 is fixed while the other end is connected to a small object of mass m lying on a frictionless table. The spring remains horizontal on the table. If the object is made to rotate at an angular velocity ω about an axis passing through fixed end, then the elongation of the spring will be: **[27 June, 2022 (Shift-II)]**

(a) $\frac{k - m\omega^2 l_0}{m\omega^2}$ (b) $\frac{m\omega^2 l_0}{k + m\omega^2}$

(c) $\frac{m\omega^2 l_0}{k - m\omega^2}$ (d) $\frac{k + m\omega^2 l_0}{m\omega^2}$

128. A particle is moving with uniform speed along the circumference of a circle of radius of radius R under the action of a central fictitious force F which is inversely proportional to R^3. Its time period of revolution will be given by: **[26 Feb, 2021 (Shift-I)]**

(a) $T \propto R^{\frac{1}{2}}$ (b) $T \propto R^{\frac{3}{2}}$ (c) $T \propto R^{\frac{4}{3}}$ (d) $T \propto R^2$

129. Statement I: A cyclist is moving on an un-banked road with a speed of 7 kmh–1 and takes a sharp circular turn along a path of radius of 2m without reducing the speed. The static friction coefficient is 0.2 The cyclist will not slip and pass the curve. (g = 9.8 m/s2)

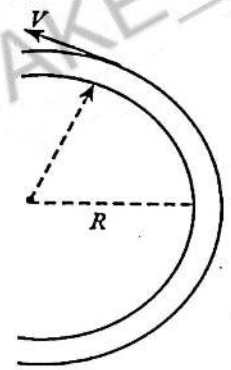
Statement II: If the road is at an angle of 45°, cyclist can cross of the curve of 2m radius with the speed of 18.5 $kmhr^{-1}$ without slipping

In the light of the above statements, choose the correct the answer from the options given below. **[16 March, 2021 (Shift-II)]**

(a) Statement I is incorrect and statement II is correct
(b) Both statement I and statement II are true
(c) Statement I is correct and statement II is incorrect
(d) Both statement I and statement II are false

130. A modern grand - prix racing car of mass m is traveling on a flat track in a circular arc of radius R with a speed v. If the coefficient of static friction between the tyres and the track is μ_s, then the magnitude of negative lift F_L acting downwards on the car is :

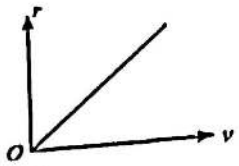
(Assume forces on the four tyres are identical and g = acceleration due to gravity) **[17 March, 2021 (Shift-I)]**

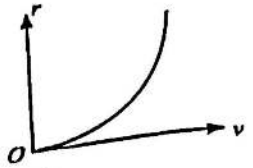


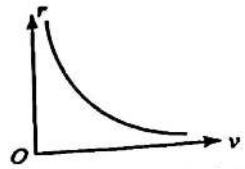
(a) $m\left(\frac{v^2}{\mu_s R} - g\right)$ (b) $-m\left(g + \frac{v^2}{\mu_s R}\right)$

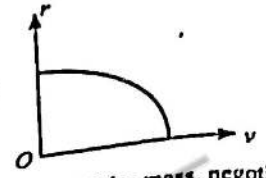
(c) $m\left(g - \frac{v^2}{\mu_s R}\right)$ (d) $m\left(\frac{v^2}{\mu_s R} + g\right)$

131. A particle of mass m moves in a circular orbit under the central potential field, $V(r) = -\frac{C}{r}$, where C is a constant. The correct radius-velocity graph of the particle's motion is: **[18 March, 2021 (Shift-II)]**

(a)


(b)


(c)


(d)


132. The normal reaction 'N' for a vehicle of 800 kg mass, negotiating a turn on a 30° banked road at maximum possible speed without skidding is ____ × 103 kg m/s². [Given cos30° = 0.87, μs = 0.2] **[20 July, 2021 (Shift-I)]**

(a) 6.96 (b) 10.2
(c) 12.4 (d) 7.2

133. A particle of mass m is suspended form a ceiling through a string of length L. The particle moves in a horizontal circle of radius r such that $r = \frac{L}{\sqrt{2}}$. The speed of particle will be: **[26 Aug, 2021 (Shift-II)]**

(a) $\sqrt{rg}$ (b) $\sqrt{\frac{rg}{2}}$

(c) $2\sqrt{rg}$ (d) $\sqrt{2rg}$

134. A particle of mass m is fixed to one end of light spring having force constant k and unstretched length ℓ. The other end is fixed. The system is given an angular speed ω about the fixed end of the spring such that it rotates in a circle in gravity free space. Then the stretch in the spring is: **[8 Jan, 2020 (Shift-I)]**

(a) $\frac{m\ell\omega^2}{k - m\omega^2}$ (b) $\frac{m\ell\omega^2}{k - \omega m}$

(c) $\frac{m\ell\omega^2}{k + m\omega^2}$ (d) $\frac{m\ell\omega^2}{k + m\omega}$

135. A body of mass $m = 10$ kg is attached to one end of a wire of length 0.3 m. The maximum angular speed (in rad s^{-1}) with which it can be rotated about its other end in space station (Breaking stress of wire = 4.8×10^7 Nm^{-2} and area of cross section of the wire = 10^{-2} cm^2) is: **[9 Jan, 2020 (Shift-I)]**

136. A spring mass system (mass m, spring constant k and natural length l) rests in equilibrium on a horizontal disc. The free and of the spring is fixed at the centre of the disc. If the disc together with spring mass system, rotates about it's axis with an angular velocity ω, ($k >> m\omega^2$) the relative change in the length of the spring is best given by the option **[9 Jan, 2020 (Shift-II)]**

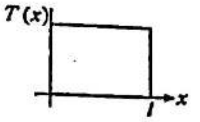
@FAKE_JEE X @FAKEDUNIT

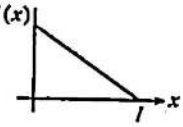
(a) $\sqrt{\frac{2}{3}}\left(\frac{m\omega^2}{k}\right)$ (b) $\frac{m\omega^2}{3k}$

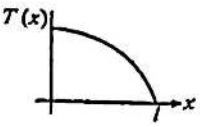
(c) $\frac{2m\omega^2}{k}$ (d) $\frac{m\omega^2}{k}$

137. A uniform rod of length l is being rotated in a horizontal plane with a constant angular speed about an axis passing through one of its ends. If the tension generated in the rod due to rotation is T(x) at a distance x from the axis, then which of the following graphs depicts it most closely? [12 April, 2019 (Shift-I)]

(a)

(b) 

(c) 

(d) 

JEE-Advanced

Laws of Motion, Application of Force/Impulse, Statics and Dynamics Involving Single System

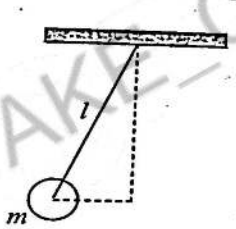
Single Correct

1. A particle of mass m is moving in the xy-plane such that its velocity at a point (x, y) is given as $\vec{v} = \alpha(y\hat{x} + 2x\hat{y})$, where α is a non-zero constant. What is the force $\vec{F}$ acting on the particle? C-16.53 W-42.74 UA-40.73 (JEE Adv. 2023)

(a) $\vec{F} = 2m\alpha^2(x\hat{x} + y\hat{y})$ (b) $\vec{F} = m\alpha^2(y\hat{x} + 2x\hat{y})$

(c) $\vec{F} = 2m\alpha^2(y\hat{x} + x\hat{y})$ (d) $\vec{F} = m\alpha^2(x\hat{x} + 2y\hat{y})$

2. A ball of mass (m) 0.5kg is attached to the end of a string having length (l) 0.5m. The ball is rotated on a horizontal circular path about vertical axis. The maximum tension that the string can bear is 324N. The maximum possible value of angular velocity of ball (in rad/s) is (IIT-JEE 2011)



(a) 9 (b) 18 (c) 27 (d) 36

3. A piece of wire is bent in the shape of a parabola $y = kx^2$ (y-axis vertical) with a bead of mass m on it. The bead can slide on the wire without friction. It stays at the lowest point of the parabola when the wire is at rest. The wire is now accelerated parallel to the x-axis with a constant acceleration a. The distance of the new equilibrium position of the bead, where the bead can stay at rest with respect to the wire, from the y axis is (IIT-JEE 2009)

(a) $\frac{a}{gk}$ (b) $\frac{a}{2gk}$ (c) $\frac{2a}{gk}$ (d) $\frac{a}{4gk}$

4. Statement-I: A cloth covers a table. Some dishes are kept on it. The cloth can be pulled out without dislodging the dishes from the table.
Statement-II: For every action there is an equal and opposite reaction. (IIT-JEE 2007)

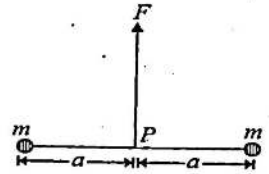
(a) If Statement-I is true, Statement-II is true; Statement-II is the correct explanation for Statement-I

(b) If Statement-I is true, Statement-II is true; Statement-II is not a correct explanation for Statement-I

(c) If Statement-I is true; Statement-II is false

(d) If Statement-I is false; Statement-II is true

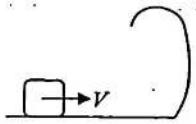
5. Two particles of mass m each are tied at the ends of a light string of length $2a$. The whole system is kept on a frictionless horizontal surface with the string held tight so that each mass is at a distance a from the center P (as shown in the figure). Now, the mid-point of the string is pulled vertically upwards with a small but constant force F. As a result, the particles move towards each other on the surface. The magnitude of acceleration, when the separation between them becomes $2x$, is (IIT-JEE 2007)

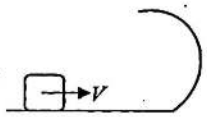


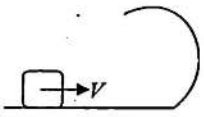
(a) $\frac{F}{2m}\frac{a}{\sqrt{a^2 - x^2}}$ (b) $\frac{F}{2m}\frac{x}{\sqrt{a^2 - x^2}}$

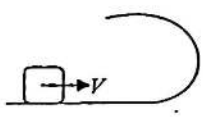
(c) $\frac{F}{2m}\frac{x}{a}$ (d) $\frac{F}{2m}\frac{\sqrt{a^2 - x^2}}{x}$

6. A small block is shot into each of the four tracks as shown below. Each of the tracks rises to the same height. The speed with which the block enters the track is the same in all cases. At the highest point of the track, the normal reaction is maximum in (IIT-JEE 2001)

(a) 

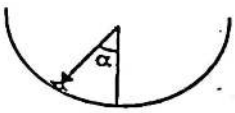
(b) 

(c) 

(d) 

@FAKE_CBSE_X @CBSE_EDUNET

7. An insect crawls up a hemispherical surface very slowly (see Fig.). The coefficient of friction between the insect and the surface is $\frac{1}{3}$. If the line joining the center of the hemispherical surface to the insect makes an angle α with the vertical, the maximum possible value of α is the given by **(IIT-JEE 2001)**



(a) $\cot\alpha = 3$ (b) $\tan\alpha = 3$ (c) $\sec\alpha = 3$ (d) $\operatorname{cosec}\alpha = 3$

8. A car is moving in a circular horizontal track of radius 10 m with a constant speed of 10 m/s. A plumb bob is suspended from the roof of the car by a light rigid rod. The angle made by the rod with the vertical is (Take = 10 m/s^2) **(IIT-JEE 1992)**

(a) 0° (b) 30° (c) 45° (d) 60°

9. A simple pendulum with a bob of mass m swings with an angular amplitude of 40°. When its angular displacement is 20°, the tension in the string is greater than $mg\cos 20°$ **(IIT-JEE 1984)**

(a) $> mg\cos 20°$ (b) $mg\cos 20°$

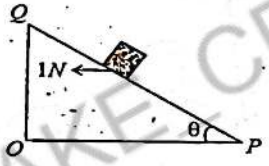
(c) mg (d) $< mg\cos 20°$

10. A ship of mass 3×10^7 kg initially at rest, is pulled by a force of 5×10^4 N through a distance of 3 m. Assuming that the resistance due to water is negligible, the speed of the ship is **(IIT-JEE 1980)**

(a) 1.5 m/s (b) 60 m/s (c) 0.1 m/s (d) 5 m/s

Multiple Correct

11. A small block of mass of 0.1 kg lies on a fixed inclined plane PQ which makes an angle θ with the horizontal. A horizontal force of 1N acts on the block through its center of mass as shown in the figure. The block remains stationary if (take g = 10 m/s^2) **C-22.83 W-72.81 UA-4.37 (IIT-JEE 2012)**



(a) $\theta = 45°$

(b) $\theta > 45°$ and a frictional force acts on the block towards P

(c) $\theta > 45°$ and a frictional force acts on the block towards Q

(d) $\theta < 45°$ and a frictional forces acts on the block towards Q

12. A simple pendulum of length L and mass (bob) M is oscillating in a plane about a vertical line between angular limits $-\phi$ and $+\phi$. For an angular displacement $\theta(|\theta| < \phi)$, the tension in the string and the velocity of the bob are T and v respectively. The following relations hold good under the above conditions **(IIT-JEE 1986)**

(a) $T\cos\theta = Mg$

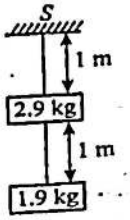
(b) $T - Mg\cos\theta = \frac{Mv^2}{L}$

(c) The magnitude of the tangential acceleration of the bob $|a_t| = g\sin\theta$

(d) $T = Mg\cos\theta$

Subjective

13. Two blocks of mass 2.9 kg and 1.9 kg are suspended from a rigid support S by two inextensible wires each of length 1 m (see figure). The upper wire has negligible mass and the lower wire has a uniform mass of 0.2 kg/m. The whole system of blocks, wires and support have an upward acceleration of 0.2 m/s². The acceleration due to gravity is 9.8 m/s².



(a) Find the tension at the midpoint of the lower wire.

(b) Find the tension at the midpoint of the upper wire. **(IIT-JEE 1989)**

14. A uniform rope of length L and mass M lying on a smooth table is pulled by a constant force F. What is the tension in the rope at a distance l from the end where the force is applied? **(IIT-JEE 1978)**

Kinetic Friction

Single Correct

15. A uniform wooden stick of mass 1.6 kg of length l rests in an inclined manner on a smooth, vertical wall of height $h(<l)$ such that a small portion of the stick extends beyond the wall. The reaction force of the wall on the stick is perpendicular to the stick. The stick makes an angle of 30° with the wall and the bottom of the stick is on a rough floor. The reaction of the wall on the stick is equal in magnitude to the reaction of the floor on the stick. The ratio $\frac{h}{l}$ and the frictional force f at the bottom of the stick are ($g = 10\ ms^{-2}$)

C-26.12 W-23.58 UA-50.3 (JEE Adv. 2016)

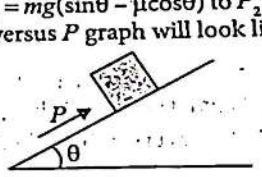
(a) $\frac{h}{l} = \frac{\sqrt{3}}{16}, f = \frac{16\sqrt{3}}{3}N$

(b) $\frac{h}{l} = \frac{3}{16}, f = \frac{16\sqrt{3}}{3}N$

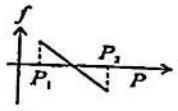
(c) $\frac{h}{l} = \frac{3\sqrt{3}}{16}, f = \frac{8\sqrt{3}}{3}N$

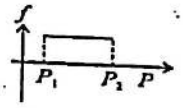
(d) $\frac{h}{l} = \frac{3\sqrt{3}}{16}, f = \frac{16\sqrt{3}}{3}N$

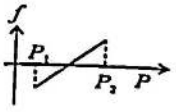
16. A block of mass m is on an inclined plane of angle θ. The coefficient of friction between the block and the plane is μ and $\tan\theta > \mu$. The block is held stationary by applying a force P parallel to the plane. The direction of force pointing up the plane is taken to be positive. As P is varied from $P_1 = mg(\sin\theta - \mu\cos\theta)$ to $P_2 = mg(\sin\theta + \mu\cos\theta)$, the frictional force f versus P graph will look like **(IIT-JEE 2010)**

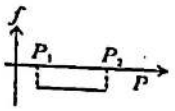


©FAKE CBSE BY @RAJ EDUNET

(b) 

(b) 

(c) 

(d) 

17. **Statement-I:** It is easier to pull a heavy object than to push it on a level ground.

Statement-II: The magnitude of frictional force depends on the nature of the two surfaces in contact. **(IIT-JEE 2008)**

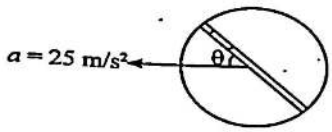
(a) If Statement-I is true, Statement-II is true; Statement-II is the correct explanation for Statement-I

(b) If Statement-I is true, Statement-II is true; Statement-II is not a correct explanation for Statement-I

(c) If Statement-I is true; Statement-II is false

(d) If Statement-I is false; Statement-II is true

18. A circular disc with a groove along its diameter is placed horizontally. Block of mass 1kg is placed as shown. The coefficient of friction between the block and all surfaces of groove in contact is $\mu = 2/5$. The disc has an acceleration of 25 m/s². Find the acceleration of the block with respect to the disc. **(IIT-JEE 2006)**



$\cos\theta = 4/5$

$\sin\theta = 3/5$

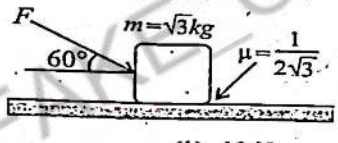
(a) 10 m/s²

(b) 5 m/s²

(c) 20 m/s²

(d) 15 m/s²

19. What is the maximum value of the force F such that the block shown in the arrangement does not move? **(IIT-JEE 2003)**



(a) 20 N

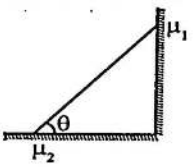
(b) 10 N

(c) 12 N

(d) 15 N

Multiple Correct

20. In the figure, a ladder of mass m is shown leaning against a wall. It is in static equilibrium making an angle θ with the horizontal floor. The coefficient of friction between the wall and the ladder is μ_1 and that between the floor and the ladder is μ_2. The normal reaction of the wall on the ladder is N_1 and that of the floor is N_2. If the ladder is about to slip, then **C-12.91 W-75.92 UA-11.18 (JEE Adv. 2014)**



(a) $\mu_1 = 0, \mu_2 \neq 0$ and $N_2 \tan\theta = \frac{mg}{2}$

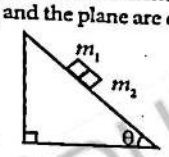
(b) $\mu_1 \neq 0, \mu_2 = 0$ and $N_2 \tan\theta = \frac{mg}{2}$

(c) $\mu_1 \neq 0, \mu_2 \neq 0$ and $N_2 = \frac{mg}{1+\mu_1\mu_2}$

(d) $\mu_1 = 0, \mu_2 \neq 0$ and $N_1 \tan\theta = \frac{mg}{2}$

Match the Column

21. A block of mass $m_1 = 1$ kg another mass $m_2 = 2$ kg are placed together (see figure) on an inclined plane with angle of inclination θ. Various values of θ are given in List-I. The coefficient of friction between the block m_1 and the plane is always zero. The coefficient of static and dynamic friction between the block m_2 and the plane are equal to $\mu = 0.3$



In List-II expressions for the friction on the block m_2 are given. Match the correct expression of the friction in List-II with the angles given in List-I, and choose the correct option. The acceleration due to gravity is denoted by g.

[Useful information $\tan(5.5°) \approx 0.1$; $\tan(11.5°) \approx 0.2$; $\tan(16.5°) \approx 0.3$]

C-17.24 W-48.85 UA-33.91 (JEE Adv. 2014)

	List-I		List-II
P.	$\theta = 5°$	1.	$m_2 g\sin\theta$
Q.	$\theta = 10°$	2.	$(m_1+m_2)g\sin\theta$
R.	$\theta = 15°$	3.	$\mu m_2 g\cos\theta$
S.	$\theta = 20°$	4.	$\mu(m_1+m_2)g\cos\theta$

(a) P-1, Q-1, R-1, S-3

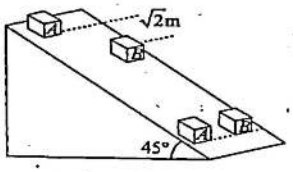
(b) P-2, Q-2, R-2, S-3

(c) P-2, Q-2, R-2, S-4

(d) P-2, Q-2, R-3, S-3

Subjective

22. Two blocks A and B of equal masses are released from an inclined plane of inclination 45° at $t = 0$. Both the blocks are initially at rest. The coefficient of kinetic friction between the block A and the inclined plane is 0.2 while it is 0.3 for block B. Initially the block A is $\sqrt{2}$ m behind the block B. When and where their front faces will come in a line? (Take g =10 m/s²) **(IIT-JEE 2004)**

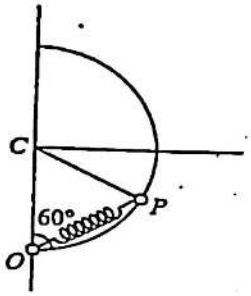


23. Two blocks of mass $m_1 = 10$ kg and $m_2 = 5$ kg connected to each other by a massless inextensible string of length 0.3 m are placed along the diameter of the turn table. The coefficient of friction between the table and m_1 is 0.5 while there is no friction between m_2 and the table. The table is rotating with an angular velocity of 10 rad/s about a vertical axis passing through its center O. The masses are placed along the diameter of table on either side of the center O such that the mass m_1 is at a distance of 0.124 m from O. The masses are observed to be at rest with respect to an observer on the turntable.

@FIITJEE OBSE X @RAJ_BOUNET

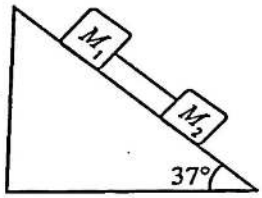
(a) Calculate the frictional force on m_1.
(b) What should be the minimum angular speed of the turntable, so that the masses will slip from this position?
(c) How should the masses be placed with the string remaining taut so that there is no frictional force acting on the mass m_1?
(IIT-JEE 1997)

24. A smooth semicircular wire track of radius R is fixed in a vertical plane (figure). One end of a massless spring of natural length $3R/4$ is attached to the lowest point O of the wire track. A small ring of mass m which can slide on the track is attached to the other end of the spring. The ring is held stationary at point P such that the spring makes an angle 60° with the vertical. The spring constant $k = mg/R$. Consider the instant when the ring is making an angle 60° with the vertical. The spring is released, (a) Draw the free body diagram of the ring. (b) Determine the tangential acceleration of the ring and the normal reaction **(IIT-JEE 1996)**



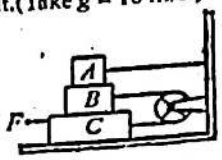
25. A hemispherical bowl of radius $R = 0.1$m is rotating about its own axis (which is vertical) with an angular velocity ω. A particle of mass 10^{-2} kg on the frictionless inner surface of the bowl is also rotating with the same ω. The particle is at a height h from the bottom of the bowl.
(a) Obtain the relation between h and ω. What is the minimum value of ω needed, in order to have a non-zero value of h?
(b) It is desired to measure g (acceleration due to gravity) using the set-up by measuring h accurately. Assuming that R and ω are known precisely and that the least count in the measurement of h is 10^{-4} m, what is minimum possible error Δg in the measured value of g? **(IIT-JEE 1993)**

26. Two blocks connected by a massless string slides down an inclined plane having an angle of inclination of 37°. The masses of the two blocks are $M_1 = 4$ kg and $M_2 = 2$ kg respectively and the coefficients of friction of M_1 and M_2 with the inclined plane are 0.75 and 0.25 respectively. Assuming the string to be taut, find (a) the common acceleration of two masses and (b) the tension in the string. ($\sin 37° = 0.6$, $\cos 37° = 0.8$). (Take $g = 9.8$. m/s²) **(IIT-JEE 1979)**



27. A block of mass 2 kg slides on an inclined plane which makes an angle of 30° with the horizontal. The coefficient of friction between the block and the surface is $\sqrt{3}/\sqrt{2}$. What force along the plane should be applied to the block so that it moves (a) down and (b) up without any acceleration? (Take $g = 10$ m/s².) **(IIT-JEE 1978)**

28. In the figure, the blocks A, B and C have masses 3 kg, 4 kg and 8 kg respectively. The coefficient of sliding friction between any two surfaces is 0.25. A is held at rest by a massless rigid rod fixed to the wall, while B and C are connected by a light flexible cord passing around a fixed frictionless pulley. Find the force F necessary to drag C along the horizontal surface to the left at a constant speed. Assume that the arrangement shown in the figure, i.e. B on C and A on B, is maintained throughout. (Take $g = 10$ m/s²). **(IIT-JEE 1978)**



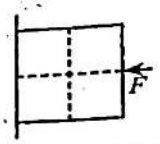
Numerical Types/Integer Type

29. A block is moving on an inclined plane making an angle 45° wi the horizontal and the coefficient of friction is μ.
The force required to just push it up the inclined plane is 3 tim the force required to just prevent it from sliding down. If we defi $N = 10\mu$, then N is **(IIT-JEE 201**

Static Friction

Single Correct

30. A block of mass m is at rest under the action of force F against a w as shown in figure. Which of the following statements is incorre **(IIT-JEE 200**



(a) $f = mg$ (where f is the frictional force)
(b) $F = N$ (where N is the normal force)
(c) F will not produce torque
(d) N will not produce torque

31. A block of mass 0.1 kg is held against a wall applying a horizo force of 5 N on the block. If the coefficient of friction between block and the wall is 0.5, the magnitude of the frictional force ac on the block is **(IIT-JEE 19**
(a) 2.5 N (b) 0.98 N (c) 4.9 N (d) 0.49 N

32. During paddling of a bicycle, the force of friction exerted by ground on the two wheels is such that it acts **(IIT-JEE 19**
(a) In the backward direction on the front wheel and in the for direction on the rear wheel
(b) In the forward direction on the front wheel and in the back direction on the rear wheel
(c) In the backward direction on both the front and the rear w
(d) In the forward direction on both the front and the rear w

33. A block of mass 1 kg lies on a horizontal surface in a truck coefficient of static friction between the block and the surface If the acceleration of the truck is 5 m/s^2, the frictional force a on the block is... **(IIT-JEE**
(a) 5N (b) 4N (c) 8N (d) 16N

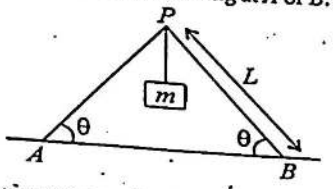
CAKE_BOX@RALEDUNET

34. A block of mass 2 kg rests on a rough inclined plane making an angle of 30° with the horizontal. The coefficient of static friction between the block and the plane is 0.7. The frictional force on the block is **(IIT-JEE 1980)**

(a) 9.8 N
(b) $0.7 \times 9.8 \times \sqrt{3}$ N.
(c) $9.8 \times \sqrt{3}$ N
(d) 0.7×9.8 N

Subjective

35. Two identical ladders are arranged as shown in the figure. Mass of each ladder is M and length L. The system is in equilibrium. Find direction and magnitude of frictional force A acting at A or B. **(IIT-JEE 2005)**

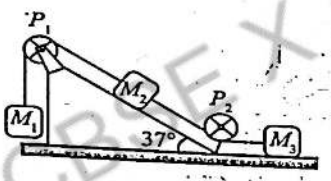


36. A block of mass m rests on a horizontal floor with which it has a coefficient of static friction μ. It is desired to make the body move by applying the minimum possible force F. Find the magnitude of F and the direction in which it has to be applied **(IIT-JEE 1987)**

Two and Three Blocks Problems

Subjective

37. Masses M_1, M_2 and M_3 are connected by strings of negligible mass which passes over massless and frictionless pulleys P_1 and P_2 as shown in figure.

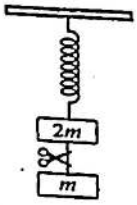


The masses move such that the portion of the string between P_1 and P_2 is parallel to the inclined plane and the portion of the string between P_2 and M_3 is horizontal. The masses M_2 and M_3 are 4.0 kg each and the coefficient of kinetic friction between the masses and the surfaces is 0.25. The inclined plane makes an angle of 37° with the horizontal.
If the mass M_1 moves downwards with a uniform velocity, find
(a) The mass of M_1,
(b) The tension in the horizontal portion of the string.
(Take $g = 9.8\ m/s^2$, $\sin 37° = 3/5$) **(IIT-JEE 1981)**

Constraint Relation, Dynamics of Multi System Spring

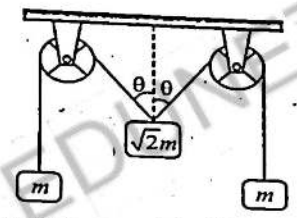
Single Correct

38. System shown in the figure is in equilibrium and at rest. The spring and string are massless, now the string is cut. The acceleration of mass $2m$ and m just after the string is cut will be **(IIT-JEE 2006)**



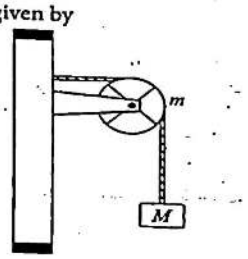
(a) $g/2$ upwards, g downwards
(b) g upwards, $g/2$ downwards
(c) g upwards, $2g$ downwards
(d) $2g$ upwards, g downwards

39. The pulleys and strings shown in the figure are smooth and of negligible mass. For the system to remain in equilibrium, the angle θ should be **(IIT-JEE 2001)**



(a) 0° (b) 30° (c) 45° (d) 60°

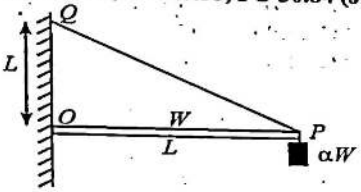
40. A string of negligible mass going over a clamped pulley of mass m supports a block of mass M as shown in the figure. The force on the pulley by the clamp is given by **(IT-JEE 2001)**



(a) $\sqrt{2}\,Mg$ (b) $\sqrt{2}\,mg$
(c) $g\sqrt{(M+m)^2+m^2}$ (d) $g\sqrt{(M+m)^2+M^2}$

Multiple Correct

41. One end of a horizontal uniform beam of weight W and length L is hinged on a vertical wall at point O and its other end is supported by a light inextensible rope. The other end of the rope is fixed at point Q. at a height L above the hinge at point O. A block of weight αW is attached at the point P of the beam, as shown in the figure (not to scale). The rope can sustain a maximum tension of $(2\sqrt{2})$ W. Which of the following statement(s) is(are) correct?
C-6.23, W-15.59, UA-47.35, PC-30.84 (JEE Adv.2021)



@PAKE CBSE X @PALEDUNET

(a) The vertical component of reaction force at O does not depend on α

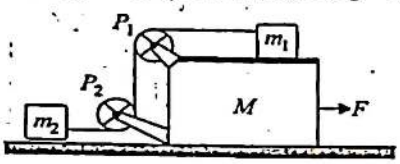
(b) The horizontal component of reaction force at O is equal to W for $\alpha = 0.5$

(c) The tension in the rope is $2W$ for $\alpha = 0.5$

(d) The rope breaks if $\alpha > 1.5$

Subjective

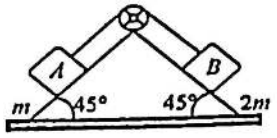
42. In the figure masses m_1, m_2 and M are 20 kg, 5 kg and 50 kg respectively. The coefficient of friction between M and ground is zero. The coefficient of friction between m_1 and M and that between m_2 and ground is 0.3. The pulleys and the strings are massless. The string is perfectly horizontal between P_1 and m_1 and also between P_2 and m_2. The string is perfectly vertical between P_1 and P_2. An external horizontal force F is applied to the mass M. (Take $g = 10\ m/s^2$).



(a) Draw a free body diagram of mass M, clearly showing all the forces.

(b) Let the magnitude of the force of friction between m_1 and M be f_1 and that between m_2 and ground be f_2. For a particular force F it is found that $f_1 = 2f_2$. Find f_1 and f_2. Write equations of motion of all the masses. Find F, tension in the string and accelerations of the masses. **(IIT-JEE 2000)**

43. Block A of mass m and block B of mass $2m$ are placed on a fixed triangular wedge by means of a massless, extensible string and a frictionless pulley as shown in figure. The wedge is inclined at 45° to the horizontal on both sides. The coefficient of friction between block A and the wedge is 2/3 and that between block B and the wedge is 1/3. If the blocks A and B are released from rest, find **(IIT-JEE 1997)**



(a) The acceleration of A,

(b) Tension in the string and

(c) The magnitude and direction of the force of friction acting on A.

Non Inertial Reference Frame and Pseudo Force

Multiple Correct

44. A reference frame attached to the earth **(IIT-JEE 1986)**

(a) Is an inertial frame by definition

(b) Cannot be an inertial frame because the earth is revolving round the sun

(c) Is an inertial frame because Newton's laws are applicable in this frame

(d) Cannot be an inertial frame because the earth is rotating about its own axis

@TAKE_OBSEX @MEDUNET

ANSWER KEY

JEE-Main

1. (d)	2. (c)	3. (b)	4. (a)	5. (c)	6. [40]	7. [2]	8. (b)	9. (d)	10. (a)
11. (a)	12. (b)	13. (a)	14. (a)	15. (a)	16. (b)	17. (c)	18. (c)	19. (b)	20. (a)
21. (d)	22. [1]	23. [500]	24. [12]	25. (d)	26. (b)	27. (c)	28. (d)	29. (b)	30. (d)
31. (a)	32. (a)	33. (c)	34. [240]	35. (a)	36. (b)	37. (a)	38. (d)	39. (b)	40. (c)
41. (b)	42. (c)	43. (b)	44. (b)	45. [12]	46. [6]	47. [3]	48. (b)	49. (b)	50. (b)
51. (b)	52. (d)	53. (b)	54. [25]	55. [492]	56. [164]	57. (b)	58. (c)	59. (b)	60. (c)
61. (c)	62. (d)	63. (a,b,d)	64. (b)	65. (c)	66. (a)	67. [30]	68. (c)	69. (b)	70. (c)
71. (a)	72. (d)	73. (c)	74. (b)	75. (d)	76. [2]	77. (d)	78. (b)	79. [25]	80. [3.3]
81. (c)	82. [5]	83. [30]	84. (c)	85. (b)	86. (a)	87. (b)	88. (Bonus)	89. (a)	90. (a)
91. (a)	92. (b)	93. (d)	94. (d)	95. (b)	96. (c)	97. (a)	98. (c)	99. [2]	100. [50]
101. (d)	102. [21]	103. [3]	104. [15]	105. (a)	106. [$\sqrt{3}$]	107. [3]	108. [346]	109. (a)	110. (a)
111. (a)	112. (b)	113. (c)	114. (b)	115. (b)	116. (b)	117. (c)	118. (c)	119. (c)	120. (b)
121. (d)	122. (a)	123. (c)	124. (c)	125. [24]	126. (b)	127. (c)	128. (d)	129. (b)	130. (a)
131. (c)	132. (b)	133. (a)	134. (a)	135. [4]	136. (d)	137. (d)			

JEE-Advanced

1. (a)	2. (d)	3. (b)	4. (b)	5. (b)	6. (a)	7. (a)	8. (c)	9. (a)	10. (c)
11. (a, c)	12. (b,c)	15. (d)	16. (a)	17. (b)	18. (a)	19. (a)	20. (c,d)	21. (d)	29. [5]
30. (d)	31. (b)	32. (a)	33. (a)	34. (a)	38. (a)	39. (c)	40. (d)	41. (a, b, d)	44. (b,d)

EXPLANATIONS

JEE-Main

1. (*d*) F_{av} = rate of change of momentum

$$\boxed{=\frac{\Delta p}{\Delta t}} \Rightarrow = \frac{0.12 \times 25}{0.1} = 30N$$

2. (*c*) Net force $= \vec{F}_1 + \vec{F}_2 = 8\hat{i} + 4\hat{j} + 4\hat{k}$

$$\vec{a} = \frac{\vec{F}}{m} = 2\hat{i} + \hat{j} + \hat{k}$$

3. (*b*) Acceleration, $a = \frac{F}{m} = \frac{kt}{m}$

Thus, a vs t will be straight line passing through origin.

4. (*a*) Here, the linear momentum of the particle,

$$\vec{P} = \cos(kt)\hat{i} - \sin(kt)\hat{j};$$

$$\vec{F} = \frac{d\vec{p}}{dt} = -k\sin(kt)\hat{i} - k\cos kt\hat{j}$$

$$\vec{F} \cdot \vec{p} = -k\sin(kt)\cos kt + k\sin kt\cos kt$$

$$= 0$$

$\Rightarrow$ angle $= 90°$

5. (*c*) The magnitude of force exerted by the ball on the hand of the player,

$$F = \frac{\Delta P}{\Delta t} = \frac{mv - 0}{0.1}$$

$$= \frac{150 \times 10^{-3} \times 20}{0.1} = 30N$$

6. [40]

$$\frac{1}{2} \times 2 \times v^2 = 10000$$

$$\Rightarrow v = 100\,m/s$$

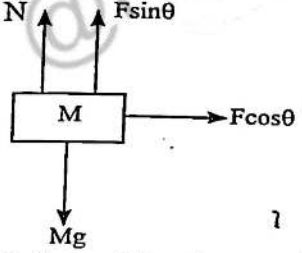
$\because v = u + at$

$$\Rightarrow v = at = a \times 5$$

$$\Rightarrow a = 20\,m/s^2 \quad [\because v = 100 \text{ m/s}]$$

$$F = ma = 2 \times 20 = 40N$$

7. [2] N



For the horizontal motion

$F\cos\theta = ma$

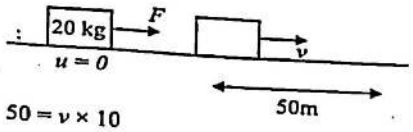
$$\Rightarrow 2\cos(kx) = \frac{mvdv}{dx} \quad [\because F = 2 \text{ and } \theta = kx]$$

$$\Rightarrow \int_0^v mvdv = 2\int_0^x \cos(kx)\,dx$$

$$\Rightarrow \frac{mv^2}{2} = \frac{2}{k}\sin kx$$

$\therefore$ *kinetic energy* $E = \frac{2}{k}\sin\theta$

8. (*b*)



$$50 = v \times 10$$

$$v = 5 \text{ m/s} \qquad [\because v = u + at]$$

$$\Rightarrow v = 0 + a \times 20$$

$$a = \frac{1}{4} m/s^2$$

$$F = ma = 20 \times \frac{1}{4} = 5N$$

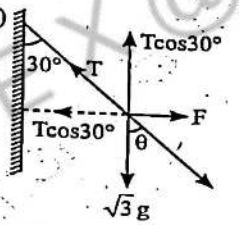
9. (*d*) Using conservation of Momentum, nmυ = MV,

$$\Rightarrow 20 \times 10^{-3} \times \frac{180}{60} \times 100 = 10 \text{ V}$$

$$\Rightarrow V = 0.6 \text{ m/s}$$

$\therefore n = 2$

10. (*a*)



$$T\cos 30° = mg$$

$$\cos 30° = \frac{\sqrt{3}g}{T} \Rightarrow \frac{\sqrt{3}}{2} = \frac{\sqrt{3}g}{T}$$

$$\Rightarrow T = 20\,N$$

11. (*a*) $\vec{v} = 2t\hat{i} + 3t^2\hat{j}$

$$\vec{a} = \frac{d\vec{v}}{dt} = 2\hat{i} + 6t\hat{j}$$

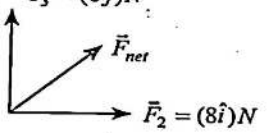
When $t = 1$ sec $\Rightarrow \vec{a} = 2\hat{i} + 6\hat{j}$

$$\therefore \vec{F} = m\vec{a} = 0.5\left(2\hat{i} + 6\hat{j}\right) = \hat{i} + 3\hat{j}$$

$$\hat{i} + x\hat{j} = i + 3\hat{j} \Rightarrow x = 3$$

12. (*b*) Fact based.

13. (*a*) $\vec{F}_3 = (6\hat{j})N$



$$\vec{F}_{net} = m\vec{a}_{net}$$

$$\vec{a}_{net} = \frac{8\hat{i} + 6\hat{j}}{5} = \frac{\sqrt{64+36}}{5} = 2$$

Acceleration of the particle, $a = 2\text{m/s}^2$

14. (*a*) Given, $\vec{a} = \frac{dv_x}{dt}\hat{x} + \frac{dv_y}{dt}\hat{y}$

$$\because \frac{dv_x}{dt} = \alpha\frac{dy}{dt} = 2\alpha^2 x$$

$$\frac{dv_y}{dt} = 2\alpha v_x = 2\alpha^2 y$$

$$\vec{F} = m\vec{a} = 2m\alpha^2(x\hat{x} + y\hat{y})$$

15. (*a*) Let additional force is $\vec{F}$, so that Fnet $= 0$

$$\vec{F} + 5\left(+\hat{i}\right) + 6\left(-\hat{i}\right) + 7\left(+\hat{j}\right) + 8\left(-\hat{j}\right) = \vec{0}$$

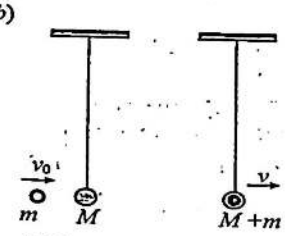
$$\Rightarrow \vec{F} - \left(\hat{i} + \hat{j}\right) = \vec{0} \Rightarrow \vec{F} = \hat{i} + \hat{j}$$

$$\Rightarrow |\vec{F}| = \sqrt{1^2 + 1^2} = \sqrt{2}N$$

$$\theta = \tan^{-1}\left(\frac{\text{Component of } \hat{j}}{\text{Component of } \hat{i}}\right)$$

$$\theta = \tan^{-1}\left(\frac{1}{1}\right) = 45°$$

16. (*b*)



JBC JAC

Given,

Mass of bag, $m_1 = 9.8$ kg; $u_1 = 0$

Mass of bullet, $m_2 = 0.2$ kg; speed of bullet, $u_2 = 10$ m/s

let the common speed of bag and bullet be v.

From the conservation of momentum

$$m_2 u_2 + m_1 \times 0 = (m_1 + m_2)\,v$$

$$\therefore v = \frac{0.2 \times 10}{9.8 + 0.2} = 0.2 \text{ m/s}$$

$$K_i = \frac{1}{2}m_2 u_2^2 = \frac{1}{2} \times 0.2 \times 100 = 10 \text{ J}$$

and $K_f = \frac{1}{2}(m_1 + m_2)v^2$

@TAKE_CBSE_X @RAJ_EDUNET

$K_f = \frac{1}{2}\times 10\times(0.2)^2 = 0.20$ J

Loss in kinetic energy $= \Delta K = K_i - K_f$

$= 10 - 0.2 = 9.8$ J

17. (c) $Ma = T - Mg$ (While climbing up)

$T_1 = M(a+g)$

$T_1 = 50(5+10) = 750$ N (Rope will break)

18. (c) Let Initial velocity of the bullet be, u

then final velocity, $v = \frac{u}{3}$

From $v^2 = u^2 + 2as$.

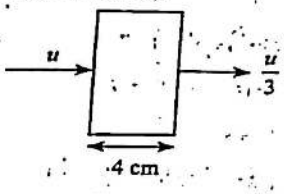
$$\left(\frac{u}{3}\right)^2 = u^2 + 2a(4) \Rightarrow a = -\frac{8u^2}{9(8)} = -\frac{u^2}{9}$$

Again, using kinematic equations

$0 = v^2 - 2a(4+x)$

$-v^2 = -2\left(\frac{v^2}{9}\right)(4+x)$

$4.5 = 4 + x = 0.5$



19. (b) $\vec{F} = \frac{d\vec{P}}{dt} = \frac{d(m\vec{v})}{dt} = \frac{dm}{dt}\times\vec{v}$

$\therefore |\vec{F}| = \left|\frac{10}{5}\times 4.5\right| g/cm^2$

$= 9\ g/cm^2 = 9$ dyne

20. (a) $N = mv2/r$.

$\Rightarrow$ The graph given in option (a) suits the best for the above relation.

21. (d) *It is given that,* $F = -\alpha x2$

$$\Rightarrow \frac{mvdv}{dx} = -\alpha x^2$$

$$\Rightarrow \int_{v_0}^{0} vdv = -\frac{\alpha}{m}\int_0^x x^2 dx \Rightarrow \frac{0^2}{2} - \frac{v_0^2}{2} = \frac{-\alpha}{3m}x^3$$

$$\Rightarrow \frac{-v_0^2}{2} = -\frac{\alpha}{3m}x^3 \Rightarrow x = \left(\frac{3v_0^2 m}{2\alpha}\right)^{1/3}$$

22. [1] $P \propto \sqrt{m}$ (if *ke* is same).

$$\therefore \frac{n}{2} = \sqrt{\frac{m_1}{m_2}} = \frac{1}{2}$$

$n = 1$

23. [500] Acceleration of the box,

$$a_x = \frac{F_x}{m} = \frac{20}{2} = 10 m/s^2$$

$$S_x = \frac{1}{2}a_x t^2 = \frac{1}{2}\times 10\times 10^2 = 500 m$$

24. [12] $\vec{F} = (2\hat{i}+3\hat{j}+5\hat{k})N$ time = 4 sec

As body start from rest therefore position vector initially $\vec{r}_i = (0\hat{i}+0\hat{j}+0\hat{k})$

and u (initial velocity) = 0 given, $r_f = (x\hat{i}+y\hat{j}+z\hat{k})$ position vector

initially $\vec{r}_i = (0\hat{i}+0\hat{j}+0\hat{k})$ u (initial velocity) = 0 given, $r_f = (x\hat{i}+y\hat{j}+z\hat{k})$

Now, from second equation of motion

$$\vec{s} = \vec{u}t + \frac{1}{2}\vec{a}t^2$$

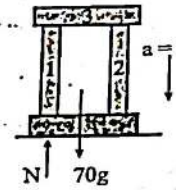
$$\Rightarrow r_f - r_i = \frac{1}{2}\times\left(\frac{2\hat{i}+3\hat{j}+5\hat{k}}{2}\right)\times(4)^2$$

$$\Rightarrow (x\hat{i}+y\hat{j}+z\hat{k}) - (0\hat{i}+0\hat{j}+0\hat{k}) = 8\hat{i}+12\hat{j}+20\hat{k}$$

$$\Rightarrow x\hat{i}+y\hat{j}+z\hat{k} = 8\hat{i}+12\hat{j}+20\hat{k}$$

$\therefore$ The value of $b = 12$

25. (d) Using free body diagram given below.



$70g - N = 70a = 70\times 0.2 = 14$

$\Rightarrow N = 700 - 14 = 686$N

26. (b) From Newton's second law,

$$\vec{a} = \frac{\vec{F}}{m} = 8\hat{i}+2\hat{j}$$

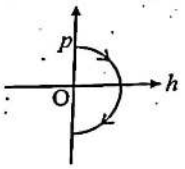
From Kinematic equation, $\vec{r} = \vec{u}t + \frac{1}{2}\vec{a}t^2$

$$\vec{r} = 0 + \frac{1}{2}(8\hat{i}+2\hat{j})10^2$$

$$\vec{r} = 400\hat{i} + 100\hat{j}$$

27. (c) Momentum $p = mv$ ...(i)

Motion under gravity $h = \frac{u^2 - v^2}{2g}$



$$h = \frac{u^2 - p^2/m}{2g} \quad (\because p = mv)$$

28. (d) $m = 20$ g, $u = 1$ m/s, $v = ?$

$S = 20\times 10^{-2}$ m

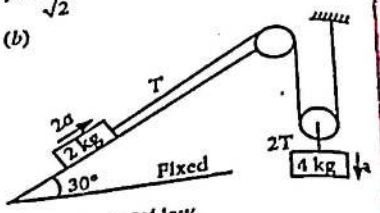
$$a = \frac{-2.5\times 10^{-2}}{20\times 10^{-3}} \text{ m/s}^2$$

Using $v^2 = u^2 + 2as$

$$v^2 = 1 - 2\times\frac{2.5\times 10^{-2}}{20\times 10^{-3}}\times\frac{20}{100}$$

$$v = \frac{1}{\sqrt{2}} \approx 0.7 m/s$$

29. (b)



By newton's 2nd law,

For 4 kg, $40 - 2T = 4a$ ...(i)

For 2 kg, $T - 10 = 2\times 2a = 4a$ ...(ii)

After solving eqn (i) and (ii), we get, $a = 5/3$

Hence, acceleration of 2kg block $= 2a = \frac{g}{3}$

30. (d) We know that, $\vec{I} = \Delta\vec{P} = \vec{P}_f - \vec{P}_i$

$P = M(\sqrt{2gh})$

$M = 0.1$ kg

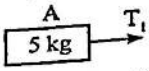
Hence,

$$I = \Delta P = 0.1\left(\sqrt{2\times 9.8\times 5} - \left(-\sqrt{2\times 9.8\times 10}\right)\right)$$

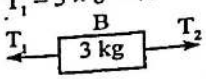
$$= 0.1\left(14 + 7\sqrt{2}\right) \approx 2.39 \text{ kg ms}^{-1}$$

31. (a) $a_A = a_B = a_C = \frac{F}{5+3+2} = \frac{80}{10}$

$= 8$ m/s²



$T_1 = 5\times 8 = 40$



$T_2 - T_1 = 3\times 8 \Rightarrow T_2 = 64$

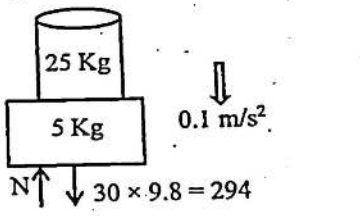
32. (a) Acceleration of system,

$$a = \frac{(m_1 - m_2)g}{(m_1 + m_2)} = \frac{g}{8}$$

$8m_1 - 8m_2 = m_1 + m_2$, $7m_1 = 9m_2$

$\therefore$ Ratio of masses, $\frac{m_1}{m_2} = \frac{9}{7}$

33. (c) Taking $g = 9.8$ m/s²



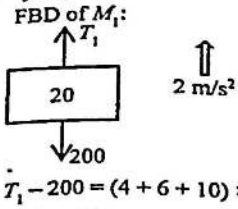
@FAKE_CBSE_@RAJ_EDUNET

By equating the force in the vertical direction

$294 - N = 3 \Rightarrow N = 291$ N

34. [240]

FBD of M_1:



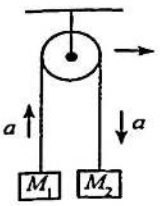
$T_1 - 200 = (4 + 6 + 10) \times 2$

$\therefore T_1 = 240$

35. (*a*) Acceleration of the system

$$a = \left(\frac{M_2 - M_1}{M_1 + M_2}\right) g$$

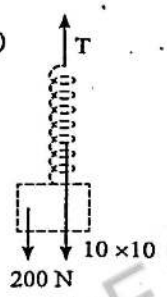
Given, $a = \frac{g}{\sqrt{2}}$



$$\frac{g}{\sqrt{2}} = \left(\frac{M_2 - M_1}{M_1 + M_2}\right) g = a$$

$$\Rightarrow \frac{M_1}{M_2} = \left(\frac{\sqrt{2} - 1}{\sqrt{2} + 1}\right)$$

36. (*b*)



Since, chain block system is in equilibrium therefore

$T = 200 + 100 = 300$ N.

37. (*a*) Acceleration of the system,

$$= \left(\frac{m_2 - m_1}{m_1 + m_2}\right) g = \frac{g}{8} \Rightarrow \frac{m_2}{m_1} = \frac{9}{7}$$

38. (*d*) Net force in the vertical and horizontal direction is zero so,

$T\sin 45° = F$ ...(i)

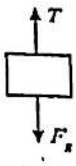
$T\cos 45° = 1 \times g$...(ii)

on dividing eq. (ii) by (i)

$\therefore \tan 45° = \frac{F}{g}$

$\therefore F = 10$ N

39. (*b*) Statement-I



When the elevator is moving with uniform speed, $T = F_s$

Statement-II

When the elevator is going down with increasing speed, its acceleration is in the downward direction.

$$W - N = \frac{W}{g} \times a$$

$$N = W\left(1 - \frac{a}{g}\right)$$ i.e. less than weight.

Force exerted by the floor is less than the weight w.

40. (*c*) $\left|\frac{d\vec{p}}{dt}\right| = |\vec{F}| \Rightarrow \frac{d\vec{p}}{dt}$ = Slope of curve

max slope (*c*), $\Rightarrow$ min slope (*b*)

41. (*b*) $P_i = Nmv\hat{i}$ and $\vec{P}_f = -Nmv\hat{i}$

where N is the number of balls that strike the wall

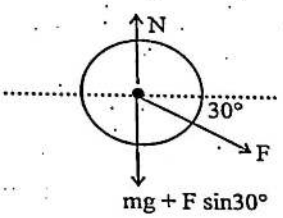
$$\Delta\vec{P} = \vec{P}_f - \vec{P}_i = -2Nmv\hat{i} = -200\,Nmv\hat{i}$$

$$\vec{F}_{Total} = \frac{\Delta\vec{P}}{\Delta t} = -\frac{200mvt}{t}$$

$$|\vec{F}| = \frac{200mv}{t}$$

42. (*c*) *Equating the vertical forces* $N = mg + F\sin 30°$

$$= 700 + 200 \times \frac{1}{2} = 800\ N.$$



43. (*b*) Impulse = Area under $F - t$ curve

(*a*) Impulse $= \frac{1}{2} \times 1 \times 0.5 = \frac{1}{4} N.s$

(*b*) Impulse $= 0.5 \times 2 = 1$ N.s (maximum)

(*c*) Impulse $= \frac{1}{2} \times 1 \times 0.75 = \frac{3}{8} N.s$

(*d*) Impulse $= \frac{1}{2} \times 2 \times 0.5 = \frac{1}{2}$ N.s

44. (*b*) Let recoil speed of gun be v

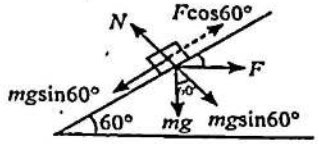
By momentum conservation

$0 = 3(-v) + 0.01(600 - v)$

$v \approx 2$ m/s

Impulse on gun = change in momentum $= 3 \times 2 = 6$ Ns

45. [12] For equilibrium of block along the inclined plane

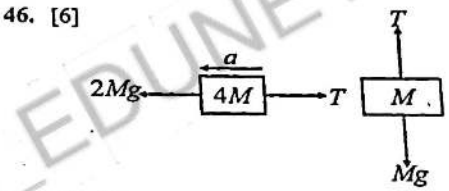


$F\cos 60° = mg\sin 60°$

$$F = 0.2 \times 10 \times \frac{\sqrt{3}}{2} \times \frac{2}{1} \Rightarrow F = \sqrt{12}\ \text{N}$$

$\Rightarrow x = 12$

46. [6]



for M

$Ma = T - Mg$ ...(i)

for 4 M

$4Ma = 2Mg - T$ ...(ii)

From (*i*) and (*ii*)

$$a = \frac{g}{5} \text{ and } T = \frac{6}{5} Mg$$

So $x = 6$

47. [3] $F_2 = 1\cos 45° + 2\cos 45°$

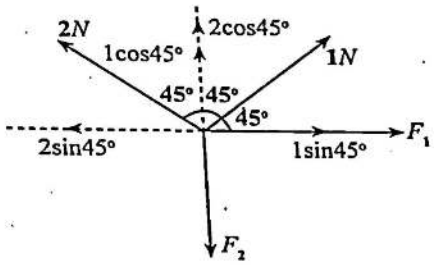
$$= 3\cos 45° = \frac{3}{\sqrt{2}}\ \text{N}$$

$F_1 + 1\sin 45° = 2\sin 45°$

$$F_1 = 1\sin 45° = \frac{1}{\sqrt{2}}\ \text{N}$$

$$\frac{F_1}{F_2} = 1:3$$

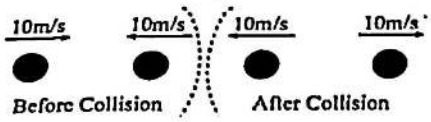
$x = 3$



@FAKE_CBSE_Y@RAJ_EDUNET

48. (*b*) From impulse momentum theorem,
Impulse = Change in momentum

$F\Delta t = \Delta p$; $F = \frac{\Delta p}{\Delta t}$



$\Delta p = 2\,mv = 2 \times 0.05 \times 10 = 1$ Ns

$\therefore F = \frac{\Delta p}{\Delta t} = \frac{2 \times 0.05 \times 10}{0.005} = 200$ N

49. (*b*) $a_1 = \frac{2M_1g - M_1g}{2M_1 + M_1} = \frac{g}{3}$

$a_2 = \frac{3M_1g - M_1g}{3M_1 + M_1} = \frac{g}{2}$

$\therefore \frac{a_1}{a_2} = \frac{2}{3}$

50. (*b*) According to Newton's IInd law of Motion,

$F = \frac{\Delta p}{\Delta t} = \frac{1.8 - (-1.8)}{\Delta t} = 100$

$\Rightarrow \Delta t = \frac{3.6}{100} = 0.036$ sec

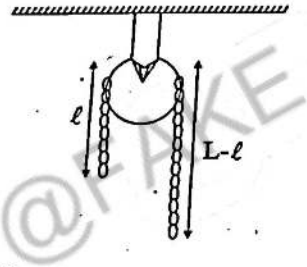
51. (*b*) $I = \Delta P$

$F_{avg} = \frac{\Delta P}{\Delta t}$

And we have, $\Delta t_1 = 3$, $\Delta t_2 = 5$

$\therefore F_1 \neq F_2$ and $I_1 = I_2$

52. (*d*) Let, Mass = m, Length = L,



$\frac{m}{L} = \lambda$

$a = \frac{F_{Pulling}}{\text{mass}} = \frac{(L-\ell)\lambda g - \lambda \ell g}{\lambda L}$

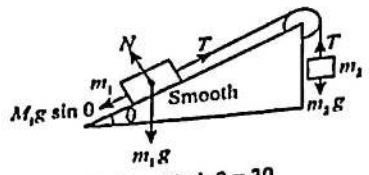
$= \frac{(L-2\ell)\lambda g}{\lambda L} = \frac{g}{2}$

$\Rightarrow L - 2\ell = \frac{L}{2}$;

$\ell = \frac{L}{4} \Rightarrow x = 4$

53. (*b*) As m_1 is in rest

$T = m_2 g = 30$ N



$T = m_1 g \sin\theta \Rightarrow 50 \sin\theta = 30$

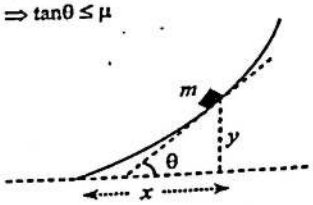
$\Rightarrow \sin\theta = \frac{3}{5} \Rightarrow \theta = 37°$

$\therefore N = 50\cos\theta = 50\cos 37°$

$= 50 \times \frac{4}{5} = 40N$

54. [25] If the block does not slide, $mg\sin\theta \leq \mu mg\cos\theta$ ...(*i*).

$\Rightarrow \tan\theta \leq \mu$



From the diagram given above,

$\tan\theta = \frac{dy}{dx} = \frac{2x}{4} = \frac{x}{2}$ ...(*ii*)

From equation (*i*) and (*ii*), we get

$\frac{x}{2} \leq \mu \Rightarrow x \leq 2\mu \Rightarrow x \leq 1$ [$\because \mu = 0.5$ given]

$\therefore y \leq \frac{1^2}{4} = 0.25m = 25$ cm

55. [492] Net accentuation in vertical direction is a,

$mg - N = ma$

$N = m(g-a) = 60 \times (10 - 1.8)$

$= 60 \times 8.2 = 492$ N

56. [164] Suppose that the magnitude of components along AB and AC are $F1$ and $F2$ respectively.

According to the question, $\vec{P} + \vec{F_1} + \vec{F_2} = \vec{0}$

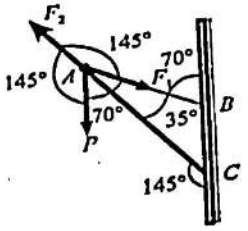
By using sign Rule, we can write

$\frac{F_1}{\sin(145^0)} = \frac{F_2}{\sin(70^0)} = \frac{P}{\sin(145^0)}$

$\Rightarrow F_2 = \frac{P\sin(180^0 - 110^0)}{\sin(110^0 + 35^0)}$

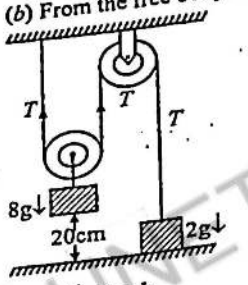
$\Rightarrow F_2 = \frac{P\sin(110^0)}{\sin(110^0)\cos(35^0) + \cos(110^0)\sin(35^0)}$

$= \frac{100 \times 0.939}{0.939 \times 0.819 - 0.342 \times 0.573} \approx 164N$



Hence, component of force along AC is $-F_2 = -164$ N

57. (*b*) From the free body diagram,



For 8 kg block,

$8g - 2T = 8a$ ...(*i*)

For 2 kg block,

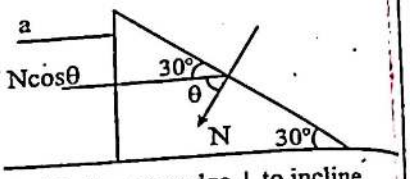
$T - 2g = 2 \times 2a$ ...(*ii*)

Solving equations (*i*) and (*ii*)

$a = \frac{g}{4} = 2.5 m/s^2$

$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 0.2}{2.5}} = 0.4s$

58. (*c*) $N\cos 60° = Ma = 16a \Rightarrow N = 32a$



For block w.r.t wedge ⊥ to incline

$N = 8g\cos 30° - 8a\sin 30°$

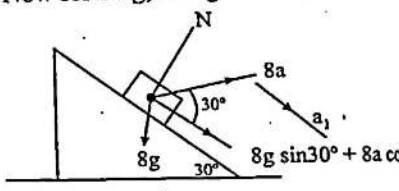
$\Rightarrow 32a = 8g\cos 30° - 8a\sin 30°$

$\Rightarrow 32a = 4\sqrt{3}g - 4a$

$\Rightarrow 36a = 4\sqrt{3}g$

$\Rightarrow a = \frac{\sqrt{3}}{9}g$

Now for 8 kg, along incline,



@FAKE_CBSE_X @RAJ_EDUNET

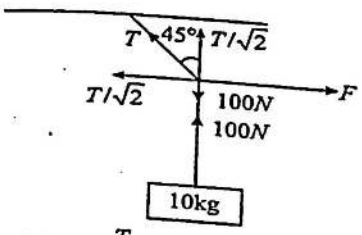
$ma_1 = 8g\sin 30° + 8a\cos 30°$

$a_1 = g\times\frac{1}{2}+\frac{\sqrt{3}}{9}g\times\frac{\sqrt{3}}{2}$

$=\frac{g}{2}+\frac{3}{18}g=\frac{2}{3}g$

59. (*b*) For upward motion
v = constant
$F = (+2N)$
For downward motion
$F = (-2N)$

60. (*c*)



$\frac{T}{\sqrt{2}}=100 \Rightarrow \frac{T}{\sqrt{2}}=F$

$F = 100$ N

61. (*c*)

$(mg + mkv^2)$

$|a| = g + kv^2$

$\Rightarrow -\frac{vdv}{dh} = g + kv^2$

$\Rightarrow \int_u^0 \frac{vdv}{g+kv^2} = \int_0^{H_{max}} -dh$

On solving

$H_{max} = \frac{1}{2K}\ln\left(1+\frac{ku^2}{g}\right)$

62. (*d*) T cos 45° = mg
$T\sin 45° = mg$
$\Rightarrow F = mg = 100$ N.

63. (a,b,d)

$\frac{dk}{dt} = \gamma t$ as $k = \frac{1}{2}mv^2$

$\therefore \frac{dk}{dt} = mv\frac{dv}{dt} = \gamma t$

$\therefore m\int_0^v vdv = \gamma\int_0^t tdt$

$\frac{mv^2}{2} = \frac{\gamma t^2}{2}$

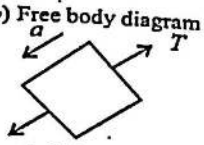
$v = \sqrt{\frac{\gamma}{m}}t$ ...(*i*)

$a = \frac{dv}{dt} = \sqrt{\frac{\gamma}{m}} =$ constant

since $F = ma$

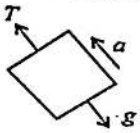
$\therefore F = m\sqrt{\frac{\gamma}{m}} = \sqrt{\gamma m} =$ constant

64. (*b*) Free body diagram for the 4 kg block



$4g\sin 60° - T = 4a$ ...(*i*)

For the 1 kg block,



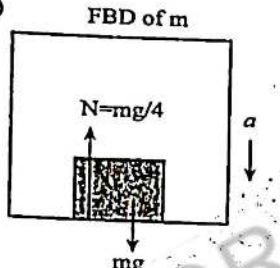
$T - g\sin 30° = a$ ...(*ii*)

Solving equation (*i*) and (*ii*)we get.

$20\sqrt{3} - T = 4T - 20$

$T = 4\left(\sqrt{3}+1\right)N$

65. (*c*)

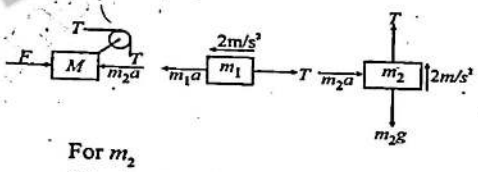


$W' = m(g-a)$

$W' = mg\left(1-\frac{a}{g}\right) = W\left(1-\frac{a}{g}\right)$

$\frac{W}{4} = W\left[1-\frac{a}{g}\right] \Rightarrow a = \frac{3g}{4}$

66. (*a*)



For m_2

$20 \times 2 = T - 200$

$T = 240$ N

For m_1

$10 \times 2 = 10a - T$

$a = 26$ m/s²

For M

$Ma = (M + m_2)a + T$

$= 120 \times 26 + 240 = 3360$ N

67. [30]

Here $\theta = \frac{60°}{2} = 30°$

Hence, angle string makes with the vertical is 30°.

68. (*c*) $k_1 = \frac{C}{\ell_1}$

$k_2 = \frac{C}{\ell_2}$

$\frac{k_1}{k_2} = \frac{C\ell_2}{\ell_1 C} = \frac{\ell_2}{n\ell_2} = \frac{1}{n}$

69. (*b*) Surface in contact effects coefficient of friction. So, depends on material of object.

70. (*c*) $fk = \mu KN = 0.04 \times 20g = 8$ Newton

$\therefore a = \frac{60-8}{26} = 2m/s^2$

71. (*a*) Due to the air friction static charge is developed. This can result in combustion. So, metallic chains is used to discharge excess charge.

72. (*d*) Using formula, $v = u + at$
$\Rightarrow 0 = 20 + (-\mu g)(5)[\because v = 0, a = -\mu g]$
$\Rightarrow \mu = 0.4$

73. (*c*) $S = ut + \frac{1}{2}at^2$

$\therefore 50 = 0 + \frac{1}{2}\times a \times 100$

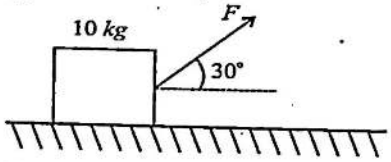
$\Rightarrow a = 1$ m/s²

$F - \mu mg = ma$

$30 - \mu \times 50 = 5 \times 1$

$\Rightarrow \mu = \frac{1}{2}$

74. (*b*)



Equating the vertical forces,

$N = Mg - F\sin 30°$

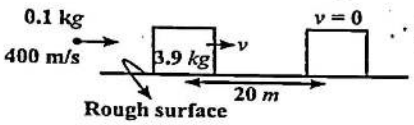
$= mg - \frac{F}{2} = \frac{200-F}{2}$

$\because F\cos 30° = \mu N$

$\sqrt{3}\frac{F}{2} = 0.25\times\left(\frac{200-F}{2}\right)$

$\Rightarrow F = \frac{200}{4\sqrt{3}+1} = 25.22N$

75. (*d*)



@FAKE_CBSE_K @RAJ_EDUNET

Applying the conservation of momentum
$P_f = P_i$ Collision)
$= (0.1 + 3.9)v = (0.1)(400)$

$\Rightarrow v = \frac{0.1 \times 400}{4} = 10 m/s$

Frictional force, $f = \mu mg$

From Newton's second law

$f = ma$

$\mu mg = ma$

$a = \mu g$

$a = \frac{\mu mg}{m} = \mu g$

From the equation of motion,

$v^2 - u^2 = 2as$

$\Rightarrow 0 - (10)^2 = 2\mu g \times 20$

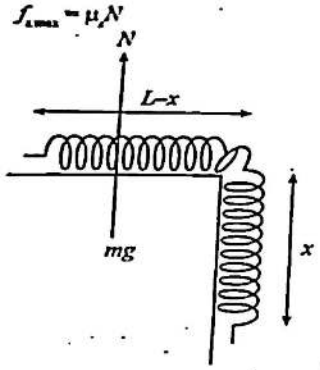
$\Rightarrow 40\mu g = 100$

$\Rightarrow \mu = \frac{1}{4}$

76. [2] Mass per unit length = l

$N = mg = \lambda(L-x)g$

$f_{s,max} = \mu_s N$



$f_{s,max} = (0.5)(\lambda)(L-x)g$

And also $f_{s,max} = m_2 g$

$0.5\lambda(L-x)g = \lambda x g$

$\frac{L-x}{2} = x$

$\frac{L}{2} = \frac{3x}{2} \Rightarrow x = \frac{L}{3} = \frac{6}{3} = 2$ m

77. (*d*) For 4 kg block

$24g - T = 4a$ ...(*i*)

For 40 kg block

$T - 40g \times 0.02 = 40\,a$ ...(*ii*)

Adding (*i*) and (*ii*)

$40 - 8 = 44a$

$a = \frac{32}{44} = \frac{8}{11}$ m/s^2

78. (*b*) In frame of belt

$a = \mu g = 4$ m/s^2, $v = 2$m/s, $u = 0$ m/s

$v^2 = u^2 + 2as$

$\Rightarrow s = 0.5$ m

79. [25]

$f = W' = 0.5 \times 10 = 5\,N$

$N = F$

The magnitude of horizontal force should be smaller man frictional force to keep it adhere to the wall.

$\Rightarrow f \le \mu N$

$\Rightarrow 5 \le 0.2\,F$

$\Rightarrow F \ge 25\,N$

80. [3.3] Net force in the Vertical direction is zero so.

$N = mg + F\sin 60°$

$f_{lim} = F\cos 60° \Rightarrow \mu N = F\cos 60°$

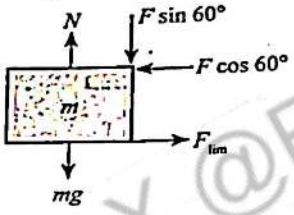
$\Rightarrow \mu(mg + F\sin 60°) = F\cos 60°$

$\Rightarrow \mu mg = F[\cos 60° - \mu \sin 60°]$

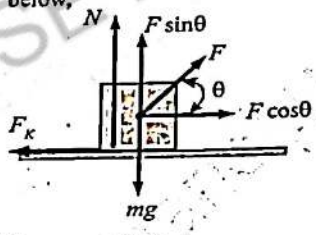
$F = \frac{\mu mg}{\cos 60° - \mu \sin 60°}$

$= \frac{\frac{1}{3\sqrt{3}} \times \sqrt{3} \times 10}{\frac{1}{2} - \frac{1}{3\sqrt{3}} \times \frac{\sqrt{3}}{2}} = \frac{10/3}{\frac{1}{2} - \frac{1}{6}}$

$= \frac{10/3}{1/3} = 10N = 3 \times \left(\frac{10}{3}\right) N$



81. (*c*) From the free body diagram given below,



$N = mg - F\sin\theta$ ...(*i*)

$ma = F\cos\theta - \mu_K N$ ...(*ii*)

On solving (*i*) and (*ii*) we get

$ma = F\cos\theta - \mu_K(mg - F\sin\theta)$

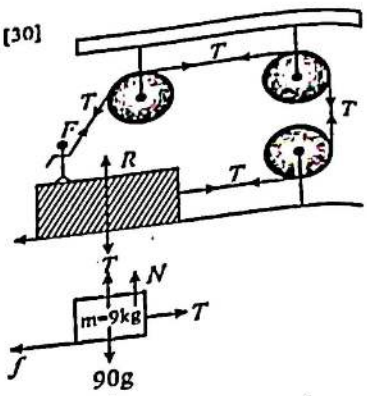
$\Rightarrow a = \frac{F}{m}\cos\theta - \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

82. [5] Minimum possible force,

$F = \frac{\mu mg}{\sqrt{1+\mu^2}}$

$F_{min} = \frac{\frac{1}{\sqrt{3}} \times 1 \times 10}{\sqrt{1 + \frac{1}{3}}} = 5\text{N}$

83. [30]



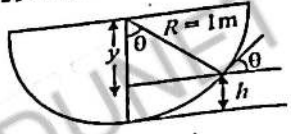
$\therefore f = T$

$\Rightarrow \mu N = T \Rightarrow \mu(90 - T) = T$

$\Rightarrow 0.5(90 - T) = T \Rightarrow 90 - T = 2T$

$\Rightarrow 3T = 90 \Rightarrow T = 30\,N$

84. (*c*)



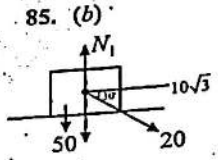
$\mu = \tan\theta$

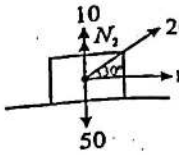
$\Rightarrow \frac{3}{4} = \tan\theta$

$\Rightarrow \theta = 37°$

$\therefore h = R - R\cos\theta = 1 - 1 \times \frac{4}{5} = 0.2$ m

85. (*b*)





$N_1 = 60, N_2 = 40$

$a_1 = \frac{10\sqrt{3} - 0.2 \times 60}{5}$

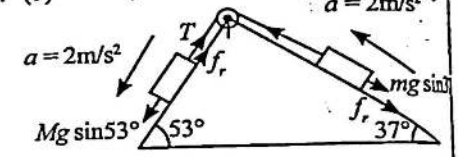
$a_2 = \frac{10\sqrt{3} - 0.2 \times 40}{5}$

86. (*a*) $y = x^2/4$, $\mu = 0.5$

$\frac{dy}{dx} = \tan\theta = \frac{x}{2} = \mu = \frac{1}{2}$

$x = 1$, $y = 1/4$

87. (*b*)



For block with M mass,

$10g\sin 53° - m(10g)\cos 53° - T = 10 \times 2$

@FAKE_CBSE_X @RAJ_EDUNET

$T = 80 - 15 - 20 = 45$ N

For block with m mass,

$T - mg\sin 37° - \mu mg\cos 37° = m \times 2$

$45 = 10$ m

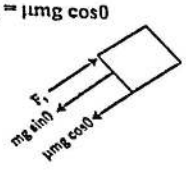
$m = 4.5$ kg

88. BONUS

Kinetic friction, $f_K = \mu mg\cos 0$

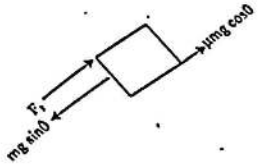
$= 0.1 \times \frac{50 \times \sqrt{3}}{2}$

$= 2.5\sqrt{3}$ N



$F_1 = mg\sin\theta + f_K$

$= 25 + 2.5\sqrt{3}$

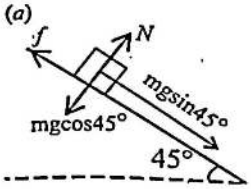


$F_2 + mg\sin\theta - f_K$

$= 25 - 2.5\sqrt{3}$

$F_1 - F_2 = 5\sqrt{3}$N

89. (a)



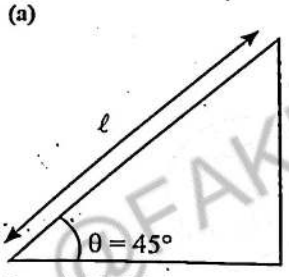
$mg\sin 45° = f = \mu_s N$ ...(i)

$mg\cos 45° = N$ ...(ii)

dividing (i) by (ii)

$\mu_s = \tan 45° = 1$

90. (a)



Case-1: No friction

acceleration of the object, a = g sinθ

Distance travelled by the object,

$\ell = \frac{1}{2}(g\sin\theta)t_1^2$

$t_1 = \sqrt{\frac{2\ell}{g\sin\theta}}$

Case-2: With friction

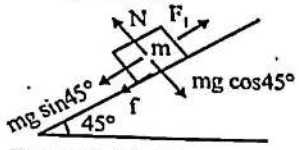
$a = g\sin\theta - \mu g\cos\theta$

$\ell = \frac{1}{2}(g\sin 0 - \mu g\cos 0)t_1^2$

$\sqrt{\frac{2\ell}{g\sin 0 - \mu g\cos 0}} = n\sqrt{\frac{2\ell}{g\sin 0}}$

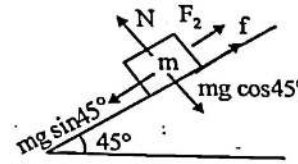
$\mu = 1 - \frac{1}{n^2}$

91. (a) Force F1 required to just push the block up the incline



$F_1 = mg\sin 45° + f$

$= \frac{mg}{\sqrt{2}} + \mu mg\cos 45° = \frac{mg}{\sqrt{2}}(1+\mu)$



Force F_2 required to prevent the block from sliding

$F_2 = mg\sin 45° - f$

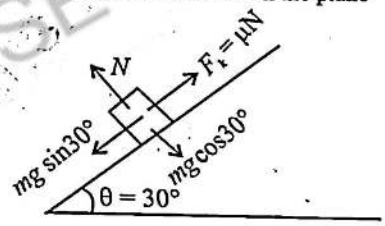
$= mg\sin 45° - \mu N = \frac{mg}{\sqrt{2}}(1-\mu)$

Given, $F_1 = 2F_2$

$\Rightarrow \frac{mg}{\sqrt{2}}(1+\mu) = 2\frac{mg}{\sqrt{2}}(1-\mu)$

$\Rightarrow \mu = 1/3 = 0.33$

92. (b) As the block slides down the plane



$\Rightarrow Mg\sin 30 - f = ma$

$\Rightarrow Mg\sin 30° - \mu mg\cos 30° = ma$

$\frac{g}{2} - \frac{\sqrt{3}}{2}\cdot\mu g = \frac{g}{4}$ $\mu = \frac{1}{2\sqrt{3}}$

93. (d) For a perfectly smooth inclined plane

$a_1 = g\sin\theta = g/\sqrt{2}$

For the rough inclined plane

$a_2 = g\sin\theta - Kg\cos\theta = \frac{g}{\sqrt{2}} - \frac{Kg}{\sqrt{2}}$

Given, $t_2 = nt_1$

and $a_1 t_1^2 = a_2 t_2^2$

$\Rightarrow \frac{g}{\sqrt{2}}t_1^2 = \left(\frac{g}{\sqrt{2}} - \frac{kg}{\sqrt{2}}\right)n^2 t_1^2$

$\Rightarrow K = 1 - \frac{1}{n^2}$

94. (d) $\omega = \frac{2\pi}{T} = \frac{2\pi}{3.14} = 2rad/s$

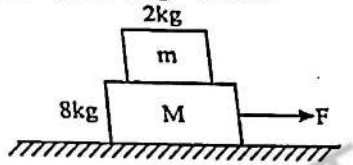
$F_{centrifugal} = M\omega^2 R = 5 \times (2)^2 \times 2 = 40$ N

95. (b) $a = -\mu g = -0.5 \times 9.8 = -4.9$ m/s2

$d = \frac{u^2}{2a} = \frac{9.8 \times 9.8}{2(4.9)}$

$= 9.8$ m

96. (c) $(aA)max = 0.5g = 4.9$ m/s2



For moving together

$F_{max} = m_T(a_A) = 10 \times 4.9$

$= 49$ N

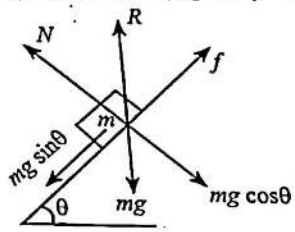
97. (a) From F. B. D

$N = Mg\cos\theta$

$f = Mg\sin\theta$

$\therefore R = \sqrt{N^2 + f^2}$

$= \sqrt{(Mg\cos\theta)^2 + (Mg\sin\theta)^2} = Mg$



98. (c) Acceleration of the block down the inclined plane, $a = g\sin\theta$ & $s = ut + \frac{1}{2}at^2$

$\ell = \frac{1}{2}g\sin 30°(2)^2$ ... (i)

$\ell = \frac{1}{2}g\sin 45°(t)^2$ ... (ii)

(i) = (ii)

$\left(\frac{1}{2}\right)(2)^2 = \frac{1}{\sqrt{2}}t^2 \Rightarrow t = \sqrt{2\sqrt{2}} \approx 1.68$

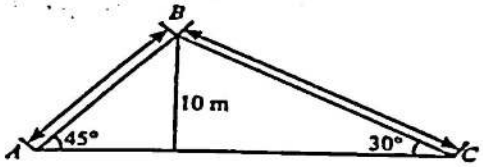
99. [2] Acceleration between A and B

$= -g\sin 45° = \frac{-g}{\sqrt{2}}$

Acceleration between B and $C = +g\sin 30°$

$= \frac{g}{2}$

@FAKE_CBSE_X_@RAJ_FUNET



Velocity at point A.

$0 = u^2 - 2\frac{g}{\sqrt{2}} \times 10\sqrt{2} \quad u = 10\sqrt{2}$ m/s

From A to B, $v = u + at$

$0 = 10\sqrt{2} - \frac{g}{\sqrt{2}} t_{AB} \qquad t_{AB} = 2s$

From B to C, $s = ut + \frac{1}{2}at^2$

$20 = 0 + \frac{1}{2} \times \frac{g}{2} t_{BC}^2 \quad t_{BC} = 2\sqrt{2}$ ...(*ii*)

$t_{AB} + t_{BC} = 2(\sqrt{2}+1) \Rightarrow t = 2$

100. [50] Given, $\ell = 0.5$ m, $A = 10^{-4} m^2$

Breaking stress, $\frac{F}{A} = 5 \times 10^8 \, N/m^2$

$\Rightarrow F = 5 \times 10^4 \, N$

$v_{(max)}^2 = \frac{T\ell}{m}$

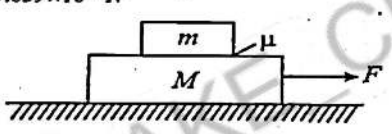
$= \frac{5 \times 10^4 \times 0.5}{10} = 50 \, m/s$

101. (*d*) The normal force by the side walls of the groove,

$F = m\omega^2 R = m\left(\frac{2\pi}{T}\right)^2 R = \frac{0.2 \times 4 \times \pi^2 \times 0.2}{40 \times 40}$

$= 9.859 \times 10^{-4} N$

102. [21]



$a = \frac{F}{M+m}$

$f = ma = m\frac{F}{M+m}$

$m\frac{F}{M+m} \le \mu mg$ (for no slipping)

$\Rightarrow F \le \mu(m+M)g$

$\therefore F_{max} = \frac{3}{7}(0.5+4.5) \times 9.8 = 21N$

103. [3] For Ascent:

$t_a = \sqrt{\frac{2\ell}{a_{ascent}}} = \sqrt{\frac{2\ell}{g(\sin\theta + \mu\cos\theta)}}$ ...(*i*)

For Descent:

$t_d = \sqrt{\frac{2\ell}{a_{descent}}} = \sqrt{\frac{2\ell}{g(\sin\theta - \mu\cos\theta)}}$ ...(*ii*)

According to question, $t_a = \frac{1}{2}t_d$

$\Rightarrow \frac{1}{\sin\theta + \mu\cos\theta} = \left(\frac{1}{4}\right)\left(\frac{1}{\sin\theta - \mu\cos\theta}\right)$

[From (*i*) and (*ii*)]

$\Rightarrow \mu = \frac{3}{5}\tan\theta = \frac{3}{5}\tan 30° = \frac{\sqrt{3}}{5}$

104. [15] $\frac{F_{net}}{1+2} = 0.5 \times 10 \Rightarrow F_{net} = 15 \, N$

105. (*a*) $R = \frac{\ell}{\theta}$

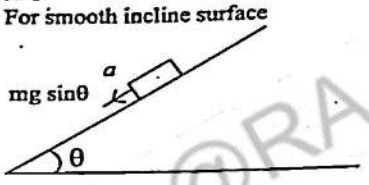
$\Rightarrow$ Time $= \frac{4 \times 2\pi R}{v} = \frac{4 \times 2\pi}{v} \times \left(\frac{\ell}{\theta}\right)$

$\Rightarrow$ Time $= \frac{4 \times 2\pi \times 4.4 \times 9.64 \times 10^{15}}{8 \times 1.5 \times 10^{11} \times \frac{4}{3600} \times \frac{\pi}{180}}$

$\Rightarrow$ Time $= 4.5 \times 10^{10}$ secs

106. [$\sqrt{3}$]

For smooth incline surface

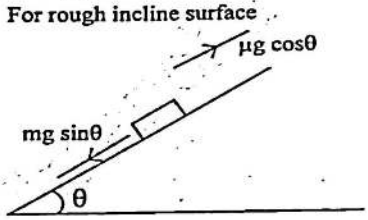


$a = g\sin 30° = \frac{g}{2}$

$S_1 = ut + \frac{1}{2}at^2$

$S_1 = \frac{1}{2}\frac{g}{2}t^2 = \frac{g}{4}t^2$ ...(*i*)

For rough incline surface



$a = g\sin\theta - \mu g\cos\theta$

$a = \left(\frac{g}{2} - \mu g \times \frac{\sqrt{3}}{2}\right) = \frac{g}{2}(1 - \mu\sqrt{3})$

$S = \frac{1}{2}a(\alpha t)^2 = \frac{1}{2}\frac{g}{2}(1-\mu\sqrt{3})\alpha^2 t^2$ ...(*ii*)

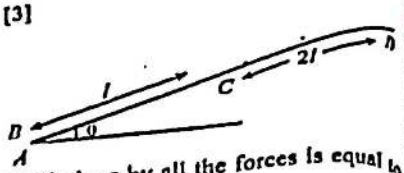
Solving (*i*) and (*ii*)

$\frac{g}{4}t^2 = \frac{g}{4}(1-\mu\sqrt{3})\alpha^2 t^2$

$\mu = \frac{1}{\sqrt{3}}\left(\frac{\alpha^2 - 1}{\alpha^2}\right)$

$\Rightarrow x = \sqrt{3}$

107. [3]



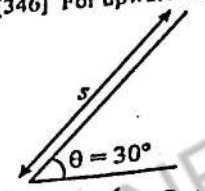
Work done by all the forces is equal to zero.

$\therefore 0 = mg3l\sin\theta - \mu mgl\cos = 0$

$3\sin\theta = \mu\cos\theta \Rightarrow \mu = 3\tan\theta$

$\therefore k = 3$.

108. [346] For upward motion



$\frac{1}{2}mv_0^2 = \left(mg\frac{S}{2} + \mu mg\frac{\sqrt{3}}{2}S\right)$

$\frac{1}{2}\frac{mv_0^2}{4} = \left(mg\frac{S}{2} - \mu mg\frac{\sqrt{3}}{2}S\right)$

For downward

$4 = \frac{(1+\mu\sqrt{3})}{(1-\mu\sqrt{3})}$

$\therefore \mu = \frac{\sqrt{3}}{5} \approx \frac{346.41}{1000}$

$I = 346$

109. (*a*) For equilibrium of the block net force be zero. Hence we can write.

$mg\sin\theta + 3 = P +$ friction

$mg\sin\theta + 3 = P + \mu mg\cos\theta$

After solving, we get, $P = 32$ N

110. (*a*) $mg\sin\theta + 2 = \mu\, mg\cos\theta$ ... (*i*)

$10 - mg\sin\theta = \mu\, mg\cos\theta$ ... (*ii*)

On adding (*i*) + (*ii*)

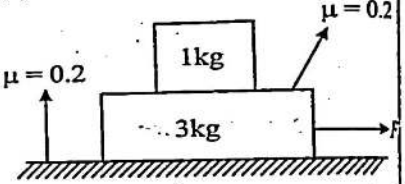
$12 = 2\,\mu mg\,\frac{\sqrt{3}}{2}$; $\mu mg = \frac{12}{\sqrt{3}}$

On (*a*) ÷ (*b*):

$8 = 2mg \times \frac{1}{2}$; mg

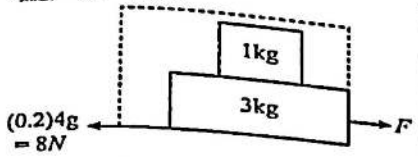
$= 8$; $\mu = \frac{\sqrt{3}}{2}$

111. (*a*)



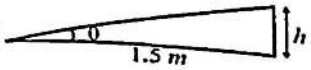
@FAKE_CBSE_K@RAJ_EDUNET

$a_{Amax} = \mu g = 2\ m/s^2$



$F - 8 = 4 \times 2 = 16\ N$

112. (b)



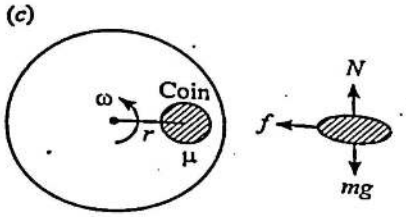
$$\tan\theta = \frac{h}{1.5}$$

$$\Rightarrow \frac{h}{1.5} = \frac{144}{4000}$$

$$\left[As\ \tan\theta = \frac{v^2}{Rg} = \frac{12\times12}{10\times400}\right]$$

$\therefore h = 5.4$ cm

113. (c)



$N = mg$

$f = m\omega^2 r$

$f = \mu N$

$\mu\, mg = mr\omega^2$

Angular velocity, $\omega = \sqrt{\frac{\mu g}{r}}$

114. (b) Given, m = 0.5 kg and l = 50cm

$T = m\omega^2\lambda$

$400 = 0.5\omega^2 \times 0.5$

$\omega = 40$ rad/s.

115. (b) Radius of the circular track is 9m

Now 120 revolution in 3 min

$$\omega = \frac{120\,\text{Rev.}}{3\ \text{min.}} = \frac{120\times2\pi rad}{3\times60\,\text{sec}} = \frac{4\pi}{3} rad/s$$

$$a_{centripetal} = \omega^2 R = \left(\frac{4\pi}{3}\right)^2 \times 9 = 16\pi^2\, m/s^2$$

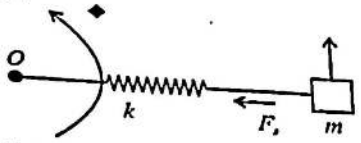
116. (b) $V_{max} = \sqrt{Rg\left[\frac{\tan\theta+\mu}{1-\mu\tan\theta}\right]}$

$$= \sqrt{300\times g\times\left[\frac{\tan30^\circ+0.2}{1-0.2\times\tan30^\circ}\right]}$$

$$= \sqrt{300\times10\times\left[\frac{0.57+0.2}{1-0.2\times0.57}\right]}$$

$V_{max} = 51.4$ m/s

117. (c)



Let, natural length of the spring = L_0

Extension in the spring = x

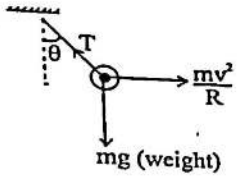
$\Rightarrow kx = m(L_0 + x)\omega^2$

$\Rightarrow 12.5x = \frac{1}{5}(L_0 + x)25$

$\Rightarrow 1.5x = L_0$

$\Rightarrow \frac{x}{L_0} = \frac{2}{3}$

118. (c)



Equating the horizontal and vertical forces,

$T\cos\theta = mg$

$T\sin\theta = \frac{mv^2}{R}$

$\Rightarrow \tan\theta = \frac{v^2}{Rg} = \frac{20^2}{40\times10}$

$\Rightarrow tan\ \theta = 1$

$\therefore \theta = \frac{\pi}{4}$

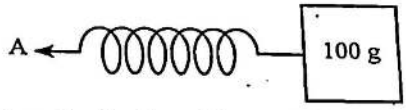
119. (c) For maximum speed in safe turning,

$\frac{mV_{max}^2}{r} = \mu mg$

$\Rightarrow V_{max} = \sqrt{\mu rg}$

$= \sqrt{0.34\times50\times10} \approx 13\, m/s$

120. (b)



Length of spring = 20 cm = 0.2m

Let extension in spring is x.

So, radius of circle = Lergth of spring + Extention

$r = 0.2 + x$

Now, Tension in spring = Centripetal force

$\therefore Kx = m\omega^2 r$

$7.5x = \left(\frac{1}{10}\right)(5^2)(0.2+x)$

$\Rightarrow \frac{15}{2}x = \frac{5}{2}\left(x+\frac{1}{5}\right)$

$\Rightarrow 3x = x + \frac{1}{5}$

$\Rightarrow x = \frac{1}{10}$

$\therefore$ Tension in spring

$= Kx = 7.5\times\frac{1}{10} = 0.75\,N$

121. (d) Frictional force would balance the centrifugal force i.e.,

$f_{s\,max} = m\omega^2 R$

$\mu mg = m\omega^2 R$

$\Rightarrow$ So when ω becomes $\frac{\omega}{2}$, R will become $4R$.

$\Rightarrow$ Therefore distance from the center will be 4 cm.

122. (a) Centripetal Force,

$F_c = m\omega^2 r = 200\times(0.2)^2\times70 = 560\,N$

123. (c) T = mw2r

$$\Rightarrow 80 = 0.1\times\left(2\pi\times\frac{K}{\pi}\times\frac{1}{60}\right)^2\times2$$

$$\Rightarrow \frac{800}{2} = \frac{K^2}{900}$$

$\Rightarrow K = 30\times20 = 600$

124. (c) T = mw2r

$$\Rightarrow 80 = 0.1\times\left(2\pi\times\frac{K}{\pi}\times\frac{1}{60}\right)^2\times2$$

$$\Rightarrow \frac{800}{2} = \frac{K^2}{900}$$

$\Rightarrow K = 30\times20 = 600$

125. [24] $f_{s\,max} = \frac{mv^2}{R}$

$\mu mg = \frac{mv^2}{R}$

$v = \sqrt{\mu Rg}$

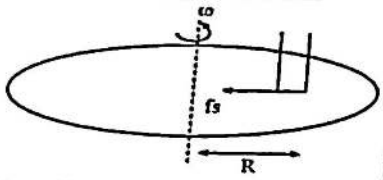
$\frac{v_2}{v_1} = \sqrt{\frac{R_2}{R_1}}$

$\frac{v_2}{30} = \sqrt{\frac{48}{75}}$

$v_2 = 24$ m/s

@TAKE_CBSE_KORAJ_EDUNET

126. (b) For beaker to move with discs



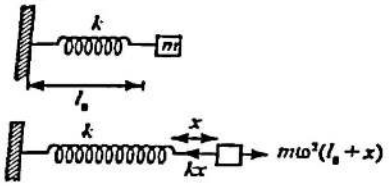
$f_s = m\omega^2 R$

We know that $f_s \le f_{s,max}$

$m\omega^2 R \le \mu mg$

$R \le \frac{\mu g}{\omega^2}$

127. (c)



$\Rightarrow kx = m\omega^2(l_0 + x)$

$kx - m\omega^2 l_0 - m\omega^2 x = 0$

$x = \frac{m\omega^2 l_0}{k - m\omega^2}$

128. (d) $F = \frac{k}{R^3} = \frac{mv^2}{R}$ (here, k = constant)

$\Rightarrow v = \sqrt{\frac{k}{mR^2}}$

$T = \frac{2\pi R}{V} = \frac{2\pi R}{\sqrt{\frac{k}{m}} \times \left(\frac{1}{R}\right)} \Rightarrow T \alpha R^2$

129. (b) Maximum velocity $v_{max} = \sqrt{\mu g r}$

[$\because \mu$ = coefficient of friction]

$\Rightarrow v_{max} = \sqrt{0.2 \times 9.8 \times 2} = 7.2$ km/hr

Since $v_{cyclist} < v_{max}$; it will turn safely.

Now, the maximum safe velocity for banked road is

$v_{max} = \sqrt{\frac{gr\tan\theta + \mu}{1 - \mu\tan\theta}} = 19.5$ km/hr

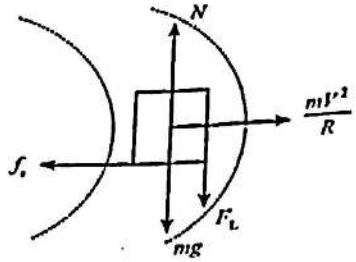
Here $v_{cyclist} < v_{max}$, it will turn safely.

130. (a) $N = mg + F_L$

$f_s \le \mu_s . N$

$\therefore \frac{mv^2}{R} \le \mu_S N$

$\frac{mv^2}{R} = \mu_S (mg - F_L) \Rightarrow -F_L = m\left(\frac{v^2}{\mu_S R} - g\right)$



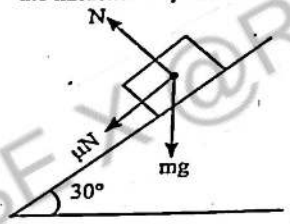
131. (c) We know that, $U = mV(r) = -\frac{Cm}{r}$

$F = -\frac{dU}{dr} = \frac{Cm}{r^2}$

The force given above will provide centripetal force.

$\therefore \frac{mv^2}{r} = \frac{Cm}{r^2} \Rightarrow r = \frac{C}{v^2}$

132. (b) Since vehicle is in equilibrium under the influence of pseudo force FP



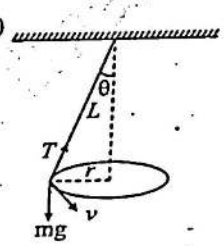
Balancing force in vertical direction

$N\cos 30° - mg - \mu N\cos 60° = 0$

$\Rightarrow N = \frac{mg}{\cos 30° - \mu\cos 60°} = \frac{80 \times 10}{(0.87 - 0.1)}$

$\approx 10.2 \times 10^3$ kgm s^{-2}

133. (a)



Given, radius of horizontal circle, $r = \frac{L}{\sqrt{2}}$

Using free body diagram,

$\sin\theta = \frac{r}{L} = \frac{1}{\sqrt{2}} \Rightarrow \theta = 45°$

$T\sin\theta = \frac{mv^2}{r}$ ...(i)

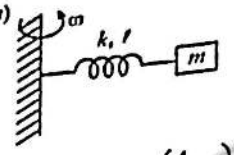
$T\cos\theta = mg$ ...(ii)

On dividing (i) with (ii), we get,

$\tan\theta = \frac{v^2}{rg}$

$\Rightarrow v = \sqrt{rg}$ [$\because \theta = 45°$]

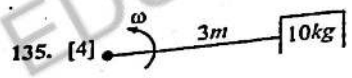
134. (a)



$m\omega^2(\ell + x) = kx ; \left(\frac{\ell}{x} + 1\right) = \frac{k}{m\omega^2}$

$x = \frac{\ell m\omega^2}{k - m\omega^2}$

135. [4]



$\frac{T}{A} = \sigma$ ...(i)

$T = m\omega^2 \lambda$ ...(ii)

Solving, $\omega = 4$ rad/s

136. (d) $m\omega^2(\ell 0 + x) = kx$

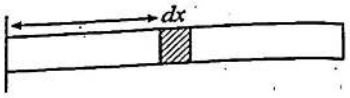
$\left(\frac{\ell_0}{x} + 1\right) = \frac{k}{m\omega^2}$

$x = \frac{\ell_0 m\omega^2}{k - m\omega^2}$

$k >> m\omega^2$

So, $\frac{x}{\ell_0}$ is equal to $\frac{m\omega^2}{k}$.

137. (d)



$T = \int_{x=x}^{x=\ell} dm\omega^2 x = \int_{x=x}^{x=\ell} \frac{m}{\ell} dx\omega^2 x$

$= \frac{m\omega^2}{2\ell}\left(\ell^2 - x^2\right)$

$T = \frac{m\omega^2}{2\ell}\left(\ell^2 - x^2\right)$

@FAKE_CBSE_X@RAJ_EDUNET

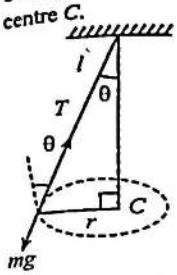
1. (a) Given, $\vec{a} = \frac{dv_x}{dt}\hat{x} + \frac{dv_y}{dt}\hat{y}$

$\because \frac{dv_x}{dt} = \alpha\frac{dy}{dt} = 2\alpha^2 x$

$\frac{dv_y}{dt} = 2\alpha v_x = 2\alpha^2 y$

$\vec{F} = m\vec{a} = 2m\alpha^2(x\hat{x} + y\hat{y})$

2. (d) $T\cos\theta$ component will cancel mg.
$T\sin\theta$ component will provide necessary centripetal force to the ball towards centre C.



$\therefore T\sin\theta = mr\omega^2 = m(l\sin\theta)\omega^2$

or $T = ml\omega^2$

$\therefore \omega = \sqrt{\frac{T}{ml}}$ or

$\omega_{max} = \sqrt{\frac{T_{max}}{ml}} = \sqrt{\frac{324}{0.5\times0.5}} = 36\ rad/s$

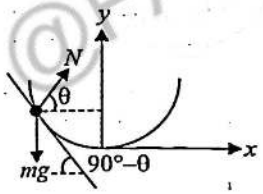
3. (b) For tangential equilibrium:
$mg\sin\theta = ma\cos\theta$

$\Rightarrow \tan\theta = \frac{a}{g}$ ...(i)

But, $\tan\theta = \frac{dy}{dx} = \frac{d}{dx}(kx^2) = 2kx$ ...(ii)

Comparing eq. (i) and (ii)

$\frac{a}{g} = 2kx \Rightarrow x = \frac{a}{2gk}$

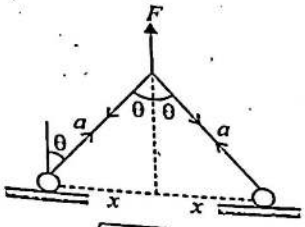


4. (b) Newton's First Law states that a body continues to be instate of rest or uniform motion until an external force acts on the body.
So, when dishes are kept on the table covered by the cloth and the cloth is pulled suddenly

JEE-Advanced

As initially the dishes are in rest the tend to be in rest while pulling the cloth if pulling is done with enough speed so that there will be negligible external force on the dishes
So Statement-I is true
Statement II is the Newton's Third Law of Motion, which is also correct
But Statement-II is not the correct explanation for Statement-I as the reason is inertia of bodies

5. (b) From the figure,



$\tan\theta = \frac{\sqrt{a^2 - x^2}}{x}$

Hence, $\cot\theta = \frac{x}{\sqrt{a^2 - x^2}}$

It is the sine component of the tension due to which is the string gets pulled.
Hence, $F = 2T\sin\theta$ ...(i)
The acceleration acts in the horizontal direction. Hence, we can say that
$T\cos\theta = ma$
where m is the mass of the body.
From (i) we get,

$\frac{F}{2\sin\theta}\cos\theta = ma$

Rewriting this we get,

$ma = \frac{F\cot\theta}{2} \Rightarrow a = \frac{F\cot\theta}{2m}$

Substituting $\cot\theta = \frac{x}{\sqrt{a^2 - x^2}}$ in this equation we get,

$\therefore a = \frac{F}{2m}\frac{x}{\sqrt{a^2 - x^2}}$

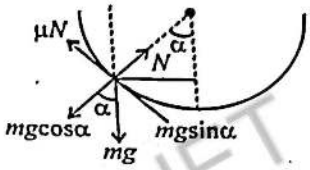
6. (a) Given, Height of all 4 blocks is the same.
from energy conservation
So, at the highest points the speed of the block in all the four cases will be the same.
Normal reaction would also be acting at highest point, and

$N \propto F_{centripetal}$

$F_{centripetal} = \frac{mv^2}{R}$;

where R is radius of curvature
$F_{centripetal} = \propto 1/R$ so
$N \propto 1/R$
Radius of curvature in the first case is minimum, so centripetal force and hence normal reaction will be maximum.

7. (a)



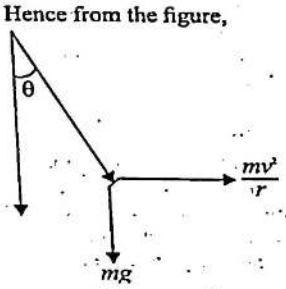
$\Rightarrow \mu N = f = mg\sin\alpha$ ...(i)
$N = mg\cos\alpha$ ...(ii)
Dividing (i) and (ii),
$\mu = \tan\alpha$

$\Rightarrow \cot\alpha = \frac{1}{\mu}$

$\therefore \cot\alpha = 3\left[\text{since}, \mu = \frac{1}{3}\right]$

So, the correct choice is (a)

8. (c) Hence from the figure,



After drawing the free body diagram of ball

$T\sin\theta = \frac{mv^2}{r}$

[through centripetal force] → (i)
$T\cos\theta = mg$ → (ii) (force)
from (i) and (ii)

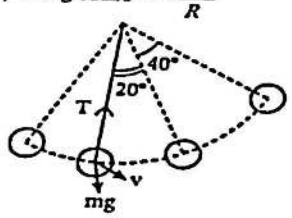
$T\sin\theta/T\cos\theta = \frac{mv^2}{r}\times\frac{1}{mg} \Rightarrow \tan\theta = \frac{v^2}{rg}$

Given that, radius = 10 m
velocity = 10 m/s
$g = 10\ m/s^2$

$\tan\theta = \frac{10^2}{10\times10} = 1 \Rightarrow \theta = 45°$

@FAKE_CBSE_KODAJ_EDUNET

9. (a) $T - mg\cos 20° = \frac{mv^2}{R}$



$\Rightarrow T = mg\cos 20° + \frac{mv^2}{R}$

$\Rightarrow T > mg\cos 20°$ (because $v \neq 0$ at 20°)

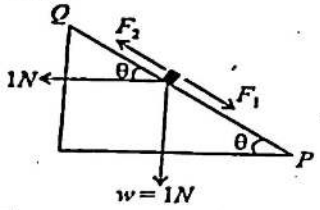
10. (c) As, $a = \frac{F}{m} = \frac{5\times10^4}{3\times10^7} = \frac{5}{3} \times 10^{-3}\ m/s^2$

So, $v = \sqrt{2as} = \sqrt{2\times\frac{5}{3}\times10^{-3}\times3}$

$= 0.1$ m/s

11. (a, c) $w = mg = 0.1 \times 10 = 1N$

F_1 = component of weight = $1\cdot\sin\theta = \sin\theta$



F_2 = component of applied force = $1\cdot\cos\theta = \cos\theta$

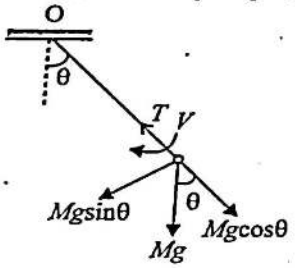
Now, at $\theta = 45°$: $F_1 = F_2$ and the block remains stationary without the help of friction.

For $\theta > 45°$: $F_1 > F_2$, so friction will act towards Q.

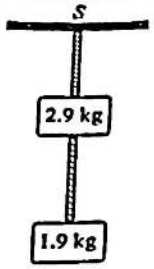
12. (b,c) Motion of the pendulum is the part of a circular motion. In circular motion, it is better to resolve the forces in two perpendicular directions. First along radius (towards center) and second along tangential. Along radius, net force should be equal to $\frac{mv^2}{R}$ and along tangent it should be equal to ma_T, where a_T is the tangential acceleration in the figure.

$T - Mg\cos\theta = \frac{Mv^2}{L}$

and $Mg\sin\theta = Ma_T$ or $a_T = g\sin\theta$



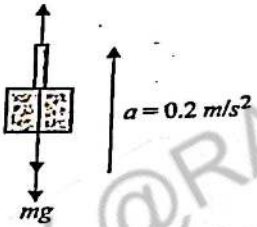
13. Given that the upper wire has no mass and the lower wire has uniform mass of 0.2 kg/m And length of each wire is 1m



(a) Let T be the tension in the middle of lower wire and the whole system is moving up with an acceleration 0.2 m/s^2 upward

Drawing the FBD of the part which is below the half of the lower wire

$m = \frac{1}{2}(0.2) = 0.1$ kg and $M = 1.9$ kg



mg = weight of the lower half of wire

Mg = weight of 1.9 kg mass block

T = Tension in the middle of lower wire

Equation of motion is

$T - (M+m)g = (M+m)a$

$T = (M+m)(g+a)$

$= (1.9+0.1)(9.8+0.2) = 2(10) = 20\ N$

(b) Similarly drawing the FBD for the portion below the middle of upper wire

Equation of motion is

$T - (2.9+0.2+1.9)g$

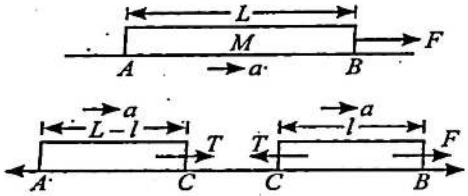
$= (2.9+0.2+1.9)a$

$T = 5(g+a)$

$T = 5(10) = 50\ N$

14. Acceleration of rope, $a = F/M$

Now, to find tension at point C, a distance l from point B, we can write equation of motion of any one part (AC or CB), both moving with acceleration a.

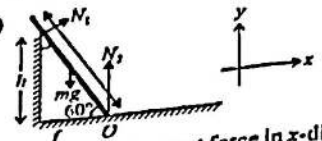


Equation of motion of part AC is

T = (mass of AC) × (acceleration)

$= \frac{M}{L}(L-l)\left(\frac{F}{M}\right) = F\left(1-\frac{l}{L}\right)$

15. (d)



Here, there is no net force in x-direction

$\Rightarrow \Sigma F_x = 0$,

$N_1\cos 30° - f = 0$ ...(I)

Also, $\Sigma F_y = 0$

$\Rightarrow N_1\sin 30° + N_2 - mg = 0$ ...(II)

Also, $\Sigma x = 0$

$mg\frac{l}{2}\cos 60° - N_2\frac{h}{\cos 30°} = 0$ ...(III)

given $N_1 = N_2$ (from question) ...(IV)

Solving Eq. (I), (II), (III) and (IV)

we have $\frac{h}{l} = \frac{3\sqrt{3}}{16}$ and $f = \frac{16\sqrt{3}}{3}$

16. (a) $P = mg(\sin\theta - \cos\theta)$

$f = \mu mg\cos\theta$ (upwards)

$P = mg\sin\theta; f = 0$

$P = mg(\sin\theta + \cos\theta)$

$f = \mu mg\cos\theta$ (downwards)

Hence, friction is first positive, then zero and then negative.

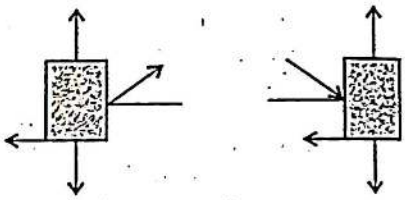
17. (b) Here in pushing, Pushing involves the vertical component of force in downward direction and so the normal reaction will be the sum of weight of block and the vertical component of pushing force. (Refer the FBD below)

Whereas, In pulling the vertical component of force is in upward direction and so the normal reaction force on block is the difference between the weight of block and the vertical component of the pulling force. (Refer the FBD below)

The resistance to motion is offered by the friction force and which is directly proportional to the normal reaction force.

Less the normal reaction force, lesser the resistance to the motion of block and block can move easily

So it is easy to pull the heavy block than pushing it



@RAJ_EDUCATE @CBSE

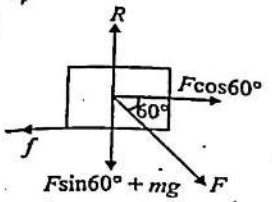
And so statement 1 is true
Frictional force also depends on nature of surface which is quantified by friction coefficient and so statement 2 is also true but not the explanation for statement 1.

18. (a) Normal reaction in vertical direction $N_1 = mg$
Normal reaction from side to the groove $N_2 = ma\sin37°$
Therefore, acceleration of block with respect to disc

$$a_r = \frac{(ma\cos37° - \mu N_1 - \mu N_2)}{m}$$

Substituting the values we get,
$a_r = 10\ m/s^2$

19. (a)



Maximum value of force applied is equal to its static friction force.
Here, friction force is $f = N$
Here, normal reaction force is:
$N = F\sin60° + mg$
Let us balance the force applied in horizontal direction with frictional force

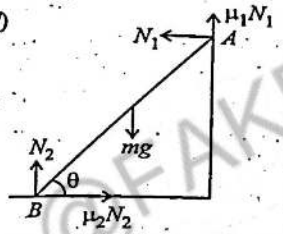
$$F\cos60° = \frac{\mu(F\sin 60° + mgF)}{2}$$

$$= \frac{(1200-40)\times(1200+40-40)}{(1200+40)\times(1200-40+40)}$$

we get

$$F = \frac{F}{2} + 10 = 20\ N$$

20. (c,d)



first we draw the free body diagram of the body
after that equate all the forces acting on the body
$N_1 = \mu_2 N_2$ [∴Horizontal equilibrium]
$mg = N_2 = \mu_1 N_1$
[∴Vertical equilibrium]
Solving the above equation we get
$mg = N_2 + \mu_1\mu_2 N_2$

$$N_2 = \frac{mg}{1+\mu_1\mu_2}$$

∴ (c) is the correct option.

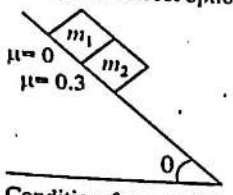
When $\mu_1 = 0$
Taking torque at P, we get

$$mg \times \frac{l}{2}\cos\theta = N_1 \times l\sin\theta$$

$$N_1 \tan\theta = \frac{mg}{2}$$

Hence, the correct option is (d)

21. (d)



Condition f or not sliding,
$f_{max} > (m_1 + m_2)g\sin\theta$
$\mu N > (m_1 + m_2)g\sin\theta$
$0.3m_2g\cos\theta \geq 30\sin\theta$
$6 \geq 30\tan\theta$
$1/5 \geq \tan\theta$
$0.2 \geq \tan\theta \Rightarrow \theta \leq \tan^{-1}(0.2) \Rightarrow \theta \leq 11.5°$
∴ f or P, $Qf = (m_1 + m_2)g\sin\theta$
(since, $\theta \leq 11.5°$)
For R and S ($\theta \geq 11.5°$ (here))
$F = f_{max} = \mu m_2 g\cos\theta$
Hence, the answer is option (d)

22. Acceleration of A down the plane,
$a_A = g\sin 45° - \mu_A g\cos 45°$

$$= (10)\left(\frac{1}{\sqrt{2}}\right) - (0.2)(10)\left(\frac{1}{\sqrt{2}}\right) = 4\sqrt{2}\ m/s^2$$

Similarly acceleration of B down the plane,
$a_B = g\sin 45° - \mu_B g\cos 45°$

$$= (10)\left(\frac{1}{\sqrt{2}}\right) - (0.3)(10)\left(\frac{1}{\sqrt{2}}\right) = 3.5\sqrt{2}\ m/s^2$$

The front face of A and B will come in a line when,

$$s_A = s_B + \sqrt{2} \text{ or } \frac{1}{2}a_A t^2 = \frac{1}{2}a_B t^2 + \sqrt{2}$$

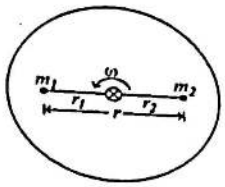
$$\frac{1}{2}\times 4\sqrt{2}\times t^2 = \frac{1}{2}\times 3.5\sqrt{2}\times t^2 + \sqrt{2}$$

Solving this equation, we get $t = 2$ s
Further,

$$s_A = \frac{1}{2}a_A t^2 = \frac{1}{2}\times 4\sqrt{2}\times (2)^2 = 8\sqrt{2}\ m$$

Hence, both the blocks will come in a line after A has travelled a distance $8\sqrt{2}$ m down the plane.

23. Given, $m_1 = 10$ kg,
$m_2 = 5$ kg, $\omega = 10$ rad/s $r = 0.3$ m
$r_1 = 0.124\ m\ r_2 = r - r_1 = 0.176$ m
(a) Masses m_1 and m_2 are at rest with respect to the rotating table. Let f be the friction between mass m_1 and table. Free body diagram of m_1 and m_2 with respect to ground



$m_1 \cdot T + fT \leftrightarrow m_2$
Therefore,
$m_1\omega^2 r_1 > T$ ...(i)
and friction on m_1 will be inward (toward center)
$f + T = m_1 r_1 \omega^2$ ...(ii)
From Eq. (i) and (ii), we get
$f = m_1 r_1 \omega^2 - m_2 r_2 \omega^2$
$f = m_1 r_1 \omega^2 - m_2 r_2 \omega^2 = (m_1 r_1 - m_2 r_2)\omega^2$ ...(iii)
$= (10 \times 0.124 - 5 \times 0.176)(10)^2\ N = 36$
Therefore, frictional force on m_1 is 36 N (inwards)

(b) From Eq. (iii)
$f = (m_1 r_1 - m_2 r_2)\omega^2$
Masses will start slipping when this force is greater than f_{max} or
$(m_1 r_1 - m_2 r_2)\omega^2 > f_{max} > \mu m_1 g$
∴ Minimum values of ω is

$$\omega_{min} = \sqrt{\frac{\mu m_1 g}{m_1 r_1 - m_2 r_2}}$$

$$= \sqrt{\frac{0.5\times 10\times 9.8}{10\times 0.124 - 5\times 0.176}}$$

$\omega_{min} = 11.67$ rad/s

$$\omega_{min} = \sqrt{\frac{\mu m_1 g}{m_1 r_1 - m_2 r_2}}$$

$$= \sqrt{\frac{0.5\times 10\times 9.8}{10\times 0.124 - 5\times 0.176}}$$

$\omega_{min} = 11.67$ rad/s

(c) From Eq. (iii), frictional force $f = 0$
where, $m_1 r_1 = m_2 r_2$
or $\frac{r_1}{r_2} = \frac{m_2}{m_1} = \frac{5}{10} = \frac{1}{2}$ and $r = r_1 + r_2$
$= 0.3\ m$
∴ $r_1 = 0.1\ m$ and $r_2 = 0.2\ m$
i.e., mass m_2 should placed at 0.2 m and m_1 at 0.1 m from the center O.

24. The free-body diagram of the ring is shown in Fig. The forces acting on the ring are:
(a) The weight mg acting vertically downwards
(b) Normal force N by the wire track.
Normal force on the ring could be either radially outwards or radially inwards depending on whether the ring presses against the inner surface or

@FAKE_CBSE_KORAJ_ENGINEER

outer surface of the track. To ascertain whether normal force is inwards or outwards, assume that, to begin with, it is inwards. Then from $F = m\vec{a}$, find the value of normal force. If it is positive, it is inwards and if it is negative, it is outwards. C. Force of the spring kx. In the given physical situation, the spring is extended, it will pull the ring. So the spring force kx is along the spring towards O.

Length of the spring in the position shown $= R$.

$CP = R$ $\angle COP = \angle OPC = 60°$ ΔCOP = Right angle Δ Change in length of the spring

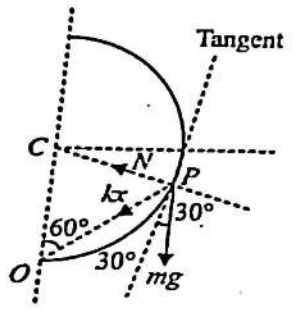
$$= R - \left(\frac{3}{4}\right)R = \left(\frac{R}{4}\right)$$

Here, $F = kx = \left(\frac{mg}{R}\right)\left(\frac{R}{4}\right) = \frac{mg}{4}$

Now from $Ft = ma_t$

$$\left(\frac{mg}{4}\right)\cos 30° + mg\cos 30° = ma_t$$

$$\Rightarrow a_t = \frac{5\sqrt{3}}{8}g$$



Normal reaction, N net force along y-axis on the ring just after the release will be zero.

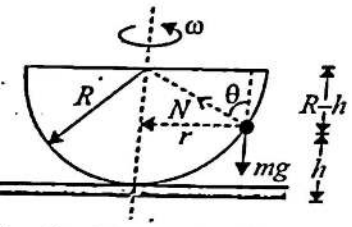
$F_y = 0$

$\therefore N + F\cos 60° = mg\cos 60°$

$\therefore N = mg\cos 60° - F\cos 60°$

$$= \frac{mg}{2} - \frac{mg}{4}\left(\frac{1}{2}\right) = \frac{mg}{2} - \frac{mg}{8}N$$

$$= \frac{3mg}{8}$$



ive, $R = 0.1$ m, $m = 10^{-2}$ kg

) FBD of particles in the ground frame of reference is shown in figure. Hence,

$\tan\theta = \frac{r}{R-h}$ $N\cos\theta = mg$ and

$N\sin\theta = mr\omega^2$

On solving above Equations, we obtain

$\tan\theta = \frac{r\omega^2}{g}$ or $\frac{r}{R-h} = \frac{r\omega^2}{g}$

or $\omega^2 = \frac{g}{R-h}$ This is the desired relation between ω and $h = R - \frac{g}{\omega^2}$

for non-zero value of, h, $R > \frac{g}{\omega^2}$ or $\omega > \sqrt{g/R}$

Therefore, minimum value of ω should be

$\omega_{min} = \sqrt{\frac{g}{R}} = \sqrt{\frac{9.8}{0.1}}$ rad/s

$\omega_{min} = 9.89$ rad/s

(b) $h = R - \frac{g}{\omega^2}$

If R and ω are known precisely,

then, $\Delta h = -\frac{\Delta g}{\omega^2}$ or $\Delta g = \omega^2 \Delta h$

(neglecting the negative sign)

$(\Delta g)_{min} = (\omega_{min})^2 \Delta h$, $(\Delta g)_{min}$

$= 9.8 \times 10^{-3}$ m/s²

26. Maximum force of friction between M_1 and inclined plane

$f_1 = \mu_1 M_1 g\cos\theta = (0.75)(4)(9.8)(0.8)$

$= 23.52$ N

$M_1 g\sin\theta = (4)(9.8)(0.6) = 23.52$ N

$= F_1$ (say)

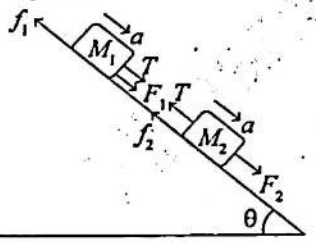
Maximum force of friction between M_2 and inclined plane

$f_2 = \mu_2 M_2 g\cos\theta$

$= (0.25)(2)(9.8)(0.8) = 3.92$ N

$M_2 g\sin\theta = (2)(9.8)(0.6) = 11.76$ N

$= F_2$ (say)



Both the blocks will be moving downwards with same acceleration a. Different forces acting on two blocks are as shown in above figure.

Equation of motion of M_1

$T + F_1 - f_1 = M_1 a$

Substituting the values of F_1, f_1 and M_1, we get

or $T = 4a$ ...(i)

Equation of motion of M_2

$F_2 - T - f_2 = M_2 a$

or $7.84 - T = 2a$ ...(ii)

Solving Eqs. (i) and (ii), we get

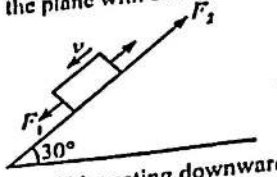
$a = 1.3$ m/s² and $T = 5.2$ N

27. $mg\sin\theta = (2)(10)\left(\frac{1}{2}\right) = 10$ N $= F_1$ (say)

$\mu mg\cos\theta = \left(\sqrt{\frac{3}{2}}\right)(2)(10)\left(\sqrt{\frac{3}{2}}\right)$

$= 21.21$ N $= F_2$ (say)

(a) Force required to move the block down the plane with constant velocity



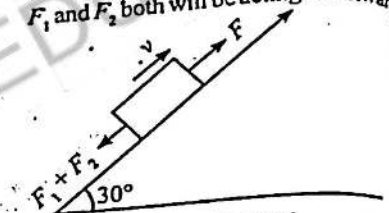
F_1 will be acting downwards, while F_2 upwards.

Since $F_2 > F_1$, force required

$F = F_2 - F_1 = 11.21$ N

(b) Force required to move the block up the plane with constant velocity.

F_1 and F_2 both will be acting downwards



$\therefore F = F_1 + F_2 = 31.21$ N

28. Maximum force of friction between A and $B = \mu m_A g$

or $f_1 = (0.25)(3)(10) = 7.5$ N

Maximum force of friction between B and $C = \mu(m_A + m_B)g$

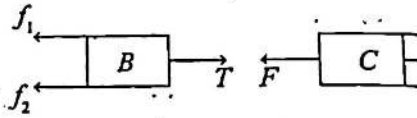
or $f_2 = (0.25)(3+4)(10) = 17.5$ N

Maximum force of friction between C and ground

$f_3 = \mu(m_A + m_B + m_C)g$

$= (0.25)(3+4+8)(10) = 37.5$ N

Block C and hence block B are moving in opposite directions with constant velocities and block A is at rest. Hence, net force on all three blocks should be zero. Free body diagrams have been shown below (Only horizontal forces are shown)

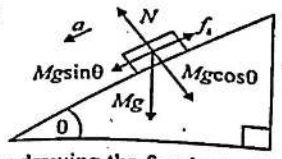


For equilibrium of B, $T = f_1 + f_2 = 25$ N

For equilibrium of C, $F = T + f_2 + f_3 = 80$

@TAKE_CARE_X @PAJ_EDUNET

29. [5]



after drawing the free body diagram, so

$F_1 = mg(\sin\theta - \mu\cos\theta)$

$F_2 = mg(\sin\theta + \mu\cos\theta)$

According to the question, $\frac{1}{3}F_2 = F_1$

$\therefore \sin\theta + \mu\cos\theta = 3(\sin\theta - \mu\cos\theta)$

$\therefore \mu = \frac{1}{2}\tan\theta = \frac{1}{2}\tan 45^\circ = \frac{1}{2}\times 1$

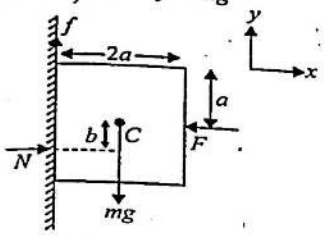
$\therefore N = 10\mu = 10\times\frac{1}{2} = 5N$

30. (*d*) The cubical block is in equilibrium

For translational equilibrium

(*a*) $\Sigma F_x = 0 \Rightarrow F = N$

(*b*) $\Sigma F_y = 0 \Rightarrow f = mg$



f = frictional force

N = normal reaction

F = force applied

For rotational equilibrium

Where τ_c = torque about c.m.

Torque created by frictional force (f) about $C = f \times a$ in clockwise direction.

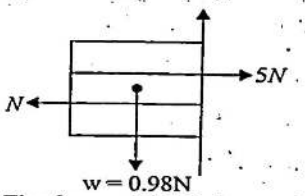
There should be another torque which should counter this torque. The normal reaction N on the block acts as shown.

This will create a torque $N \times b$ in the anticlockwise direction.

Such that $f \times a = N \times b$

N will produce a torque so option *d* is incorrect and that is the answer for the solution.

31. (*b*)



The force which helps us in moving while coming in contact with earth surface.

Finding the limiting value of frictional force.

$f_{max} = \mu N = 0.5 \times 5 = 2.5\ N$

Now, value of $mg = 0.1 \times 9.8 = 0.98\ N$

$f_{max} > mg$

Finding the value of frictional force applied on block

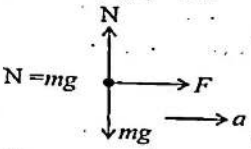
$f = mg = 0.98\ N$

32. (*a*) Because the back wheel moves in the forward direction during padding, but the point where the wheel touches the ground is in the backward direction, friction will be in the forward direction in the rear wheel, but because the front wheel is not receiving any torque, it will be stationary, and the forces that cause the rotation are only frictional forces.

Hence the Correct answer is (*a*)

33. (*a*) Here the block will move due to frictional force

$f = ma = (1)(5) = 5N$

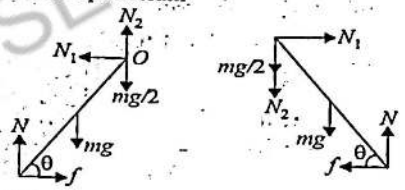


34. (*a*) Since, $\mu mg\cos\theta > mg\sin\theta$. So block is in rest.

$\therefore$ Force of friction is $f = mg\sin\theta$

$2 \times 9.8 \times \frac{1}{2} = 9.8\ N$

35. Drawing the FBD of both rods as the rods are in equilibrium



$\Sigma F_x = 0$

$\Sigma F_y = 0$

$\tau_{net} = 0$

For right rod

$N_2 + \frac{mg}{2} + Mg = N$ ...(*i*)

$N_1 = f$ ...(*ii*)

For left rod

$N_2 + N = Mg + \frac{mg}{2}$ ...(*iii*)

From (*i*) and (*iii*)

$N_1 = f = N_2 = 0 = N = Mg + \frac{mg}{2}$

Balancing torque at point O, (on left Rod)

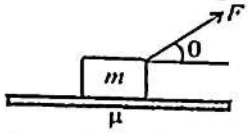
$Mg\frac{L}{2}\cos\theta + fL\sin\theta = NL\cos\theta$

$\frac{Mg\cos\theta}{2} + f\sin\theta = \left(mg + \frac{mg}{2}\right)\cos\theta$

$f = \left(\frac{Mg}{2} + \frac{mg}{2}\right)\cot\theta$

$\Rightarrow f = \left(\frac{M+m}{2}\right)g\cot\theta$

36. Let F be applied at angle θ as shown in



For vertical equilibrium,

$N + F\sin\theta = mg \Rightarrow N = mg - F\sin\theta$ ...(*i*)

for horizontal motion

$F\cos\theta \geq f_l \Rightarrow F\cos\theta \geq \mu N$[as $f_l = \mu N$] ...(*ii*)

substituting value of N from equation (*i*) in (*ii*)

$F\cos\theta \geq \mu(mg - F\sin\theta)$

$\Rightarrow F \geq \frac{\mu mg}{(\cos\theta + \mu\sin\theta)}$

For the force F to be minimum ($\cos\theta + \mu\sin\theta$) must be maximum. Maximum value of $\cos\theta + \mu\sin\theta$ is $\sqrt{(1+\mu^2)}$

so that $F_{min} = \frac{\mu mg}{\sqrt{1+\mu^2}}$ with $\theta = \tan^{-1}(\mu)$

37. Constant velocity denotes that the system's net acceleration is zero. The system's net pulling force is zero. Tension forces are not included when determining the pulling force. Therefore,

(*a*) $M_1 g = M_2 g\sin 37^\circ + \mu M_2 g\cos 37 + \mu M_3 g$

or $M_1 = M_2\sin 37^\circ + \mu M_2\cos 37 + M_3$

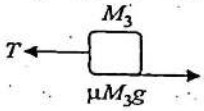
Substituting the values

$M = (4)\ \frac{3}{5} + (0.25)(4)\frac{4}{5} + (0.25)(4)$

$= 4.2$ kg

(*b*) Since, M_3 is moving with uniform velocity

$T = \mu M_3 g = (0.25)\ (4)\ (9.8) = 9.8\ N$



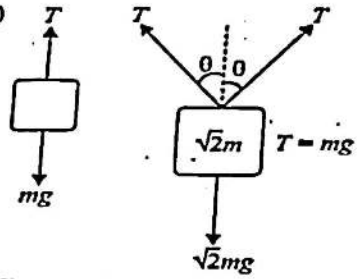
38. (*a*) Initially under equilibrium of mass m, $T = mg$

Now, the string is cut. Therefore, $T = mg$ force is decreased on mass m upwards and downwards on mass $2m$.

$a_m = \frac{mg}{m} = g \quad a_{2m} = \frac{mg}{2m} = \frac{g}{2}$

@THEJEEBSE KORAJ_EDUNET

39. (c)



$T = mg$

Free body diagram of m is

$T = mg$

Free body diagram of mass $\sqrt{2}m$ is

$2T\cos\theta = \sqrt{2}mg$

Dividing Eq. (*ii*) by Eq. (*i*), we get

$\cos\theta = \frac{1}{\sqrt{2}}$ or $\theta = 45°$

40. (d) Free body diagram of the pulley is shown in figure. Pulley is in equilibrium under four forces. Three forces as shown in figure and the fourth, which is equal and opposite to the resultant of these three forces, is the force applied by the clamp on the pulley (say F).

Weight of the pulley mg acts downwards.

Weight of the block Mg acts downwards.

Total downward force. $F_1 = (m + M)g$

Tension in the string. $T = Mg$

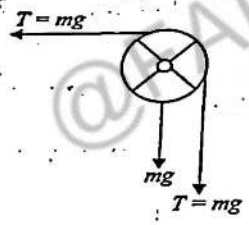
The force on the pulley by reaction of the clamp is equal to the resultant of F_1 and T. Let it be F.

$F^2 = T^2 = F_2^1 = (Mg)^2 + [(m + M)g]^2$

or $F^2 = [M^2 + (M + m)^2]g^2$

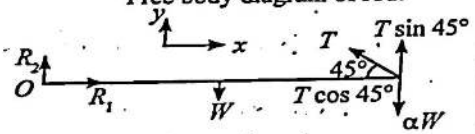
or $g\sqrt{(M+m)^2 + M^2} = F$

$\Rightarrow F = g\sqrt{(M+m)^2 + M^2}$



41. (a, b, d)

Free body diagram of rod:



$\Sigma F_x = 0$

$R_1 = T\cos 45°$

$R_1 = \frac{T}{\sqrt{2}}$ ...(*i*)

$\Sigma F_y = 0$

$R_2 + T\sin 45° = W + \alpha W$

$R_2 + \frac{T}{\sqrt{2}} = W(1 + \alpha)$ ...(*ii*)

$\Sigma\tau_0 = 0$

$W\frac{L}{2} + \alpha WL = \frac{T}{\sqrt{2}}L$

$T = \sqrt{2}W\left[\alpha + \frac{1}{2}\right]$ ...(*iii*)

From (*ii*) and (*iii*)

$R_2 + W\left[\alpha + \frac{1}{2}\right] = W(1 + \alpha)$

$R_2 = \frac{W}{2}$

Hence, option (*a*) is correct.

From equation (*iii*) if $\alpha = 0.5$

$T = \sqrt{2}$ W

$T_{max} = 2\sqrt{2}$ W

For rope to break

$T > 2\sqrt{2}$ W

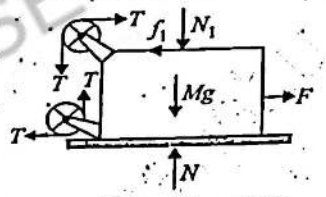
$\sqrt{2}W\left[\alpha + \frac{1}{2}\right] > 2\sqrt{2}W$

$\alpha > \frac{3}{2}$

Hence, option (*d*) is correct.

42. Given, $m_1 = 20$ kg, $m_2 = 5$ kg, $M = 50$ kg, $\mu = 0.3$ and $g = 10$ m/s²

(*a*) Free body diagram of mass M is given as



(*b*) The maximum value of f_1 is

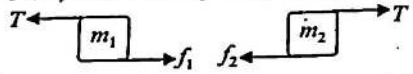
$(f_1)_{max} = (0.3)(20)(10) = 60$ N

The maximum value of f_2 is

$(f_2)_{max} = (0.3)(5)(10) = 15$ N

Forces on m_1 and m_2 in horizontal direction are as follows

Now, there are only two possibilities:



(1) Either both m_1 and m_2 will remain stationary (with respect to the ground) or

(2) Maybe both m_1 and m_2 will remain stationary (with respect to the ground) or When the first case is possible,

and

$T \le (f_1)_{max}$ or $T \le 60$ N

$T \le (f_2)_{max}$ or $T \le 15$ N

These conditions will be satisfied when $T \le 15$ N say $T = 14$ N, then $f_1 = f_2 = 14$ N

Therefore, the condition $f_1 = 2f_2$ will not be satisfied. Thus, m_1 and m_2 both cannot remain stationary.

In the second case, when m_1 and m_2 both move

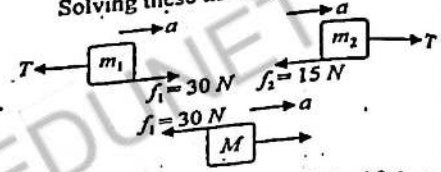
$f_2 = (f_2)_{max}$ 15 N $f_1 = 2f_2 = 30$ N

Now, since $f_1 < (f_1)_{max}$, there is no relative motion between m_1 and M i.e. all the masses move with same acceleration, say a

$\therefore f_2 = 15$ N and $f_1 = 30$ N

Free body diagrams and equations of motion are as follows

Solving these three equations, we get



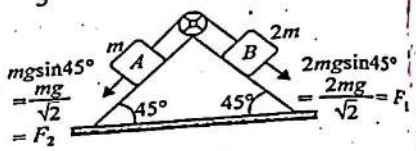
$F = 60$ N, $T = 18$ N, $a = 0.6$ m/s² $f_1 = 30$ N, $f_2 = 15$ N

43. (a) Acceleration of block A

Maximum friction force that can be obtained at A is

$(f_{max})_A = \mu_A(mg\cos 45°)$

$= \frac{2}{3}(mg/\sqrt{2}) = \frac{\sqrt{2}mg}{3}$



Similarly,

$(f_{max})B = \mu_B(2mg\cos 45°) = 13(2mg/\sqrt{2})$

$= \frac{\sqrt{2}mg}{3}$ ...(*i*)

Therefore, maximum value of friction that can be obtained on the system is

$f_{max} = (f_{max})_A + (f_{max})_B = \frac{2\sqrt{2}mg}{3}$

Net pulling force on the system is

$F = F_1 - F_2 = \frac{2mg}{\sqrt{2}} - \frac{mg}{\sqrt{2}} = \frac{mg}{\sqrt{2}}$ ...(*ii*)

From Eq. (*i*) and (*ii*), we can see that Net pulling force $< f_{max}$.

Therefore, the system will not move or that acceleration of block A will be zero.

@TAKE_CBSE_@RAJ_EDUNET

(b) Now, for tension T in the string, we may consider either equilibrium of A or B. Equilibrium of A gives

$$T = F_2 + f_A = \frac{mg}{\sqrt{2}} + \frac{mg}{3\sqrt{2}} = \frac{4mg}{3\sqrt{2}}$$

or $$T = \frac{2\sqrt{2}mg}{3}$$

Similarly, equilibrium of B gives

$$T + f_B = F_1 \text{ or } T = F_1 - f_B$$

$$= \frac{2mg}{\sqrt{2}} - \frac{\sqrt{2}mg}{3} = \frac{4mg}{3\sqrt{2}} \text{ or } = \frac{2\sqrt{2}mg}{3}$$

Therefore, tension in the string is $\frac{2\sqrt{2}mg}{3}$

(c) Net pulling force on the system (block A and B)

$$F = F_1 - F_2 = mg/\sqrt{2}$$

Therefore, total friction force on the blocks should also be equal to $\frac{mg}{\sqrt{2}}$ or

$$f_A + f_B = F = mg/\sqrt{2}$$

Now, since that blocks will start moving from block B first (if they move), therefore, f_B will reach its limiting value first and if still some force is needed, it will be provided by f_A.

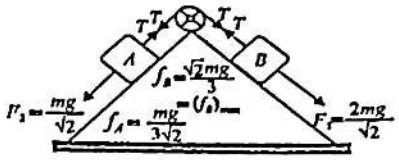
Here, $(f_{max})B < F$

Therefore, f_B will be in its limiting value and rest will be provided by f_A.

Hence, $f_B = (f_{max})_B = \frac{\sqrt{2}mg}{3}$ and

$$f_A = F - f_B = \frac{mg}{\sqrt{2}} - \frac{\sqrt{2}mg}{3} = \frac{mg}{3\sqrt{2}}$$

The FBD of the whole system will be as shown in the figure.



Therefore, friction on A is

$f_A = mg/3\sqrt{2}$ (down the plane)

44. (b,d) A reference frame attached to the earth is cannot be an inertial frame because the earth is revolving around the sun and rotating about its own axis.

The correct option is (b) and (d).

@FAKE_CBSE X @RAJ_EDUNET

6 Work, Power and Energy

Scan for Sol.

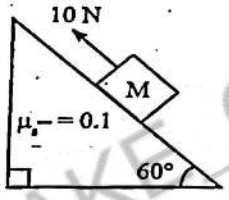
JEE-Main

Work Done by Constant Force, Variable Force, Kinetic Energy

1. Two bodies of mass 4g and 25g are moving with equal kinetic energies. The ratio of magnitude of their linear momentum is: [27 Jan, 2024 (Shift-I)]
(a) 3 : 5 (b) 5 : 4 (c) 2 : 5 (d) 4 : 5

2. A block of mass 100kg slides over a distance of 10 m on a horizontal surface. If the co-efficient of friction between the surface is 0.4, then the work done against friction (in J) is: [29 Jan, 2024 (Shift-I)]
(a) 4200 (b) 3900 (c) 4000 (d) 4500

3. A block of mass 1 kg is pushed up a surface inclined to horizontal at an angle of 60° by a force of 10 N parallel to the inclined surface as shown in figure. When the block is pushed up by 10 m along inclined surface, the work done against frictional force is: [g = 10 m/s²] [30 Jan, 2024 (Shift-II)]



(a) $5\sqrt{3}$ J (b) 5 J (c) 5×10^3 J (d) 10 J

4. An artillery piece of mass M_1 fires a shell of mass M_2 horizontally. Instantaneously after the firing, the ratio of kinetic energy of the artillery and that of the shell is: [31 Jan, 2024 (Shift-I)]
(a) $M_1/(M_1 + M_2)$ (b) $\frac{M_2}{M_1}$
(c) $M_2/(M_1 + M_2)$ (d) $\frac{M_1}{M_2}$

5. A bullet of mass 50 g is fired with a speed 100 m/s on a plywood and emerges with 40 m/s. The percentage loss of kinetic energy is: [06 April, 2024 (Shift-I)]
(a) 32% (b) 44% (c) 16% (d) 84%

6. Four particles A, B, C, D of mass $m/2$, m, $2m$, $4m$, have same momentum, respectively. The particle with maximum kinetic energy is: [06 April, 2024 (Shift-I)]
(a) D (b) C (c) A (d) B

7. When kinetic energy of a body becomes 36 times of its original value, the percentage increase in the momentum of the body will be: [06 April, 2024 (Shift-II)]
(a) 500% (b) 600% (c) 6% (d) 60%

8. Three bodies A, B and C have equal kinetic energies and their masses are 400 g, 1.2 kg and 1.6 kg respectively. The ratio of their linear momenta is: [08 April, 2024 (Shift-I)]
(a) $1 : \sqrt{3} : 2$ (b) $1 : \sqrt{3} : \sqrt{2}$
(c) $\sqrt{2} : \sqrt{3} : 1$ (d) $\sqrt{3} : \sqrt{2} : 1$

9. A force $(3x^2 + 2x - 5)$ N displaces a body from $x = 2$ m to $x = 4$ m. Work done by this force is ..... J. [09 April, 2024 (Shift-II)]

10. Identify the correct statements from the following:
A. Work done by a person in lifting a bucket out of a well by means of a rope tied to the bucket is negative.
B. Work done by gravitational force in lifting a bucket out of a well by a rope tied to the bucket is negative.
C. Work done by friction on a body sliding down an inclined plane is positive.
D. Work done by an applied force on a body moving on a rough horizontal plane with uniform velocity is zero.
E. Work done by the air resistance on an oscillating pendulum is negative.
Choose the correct answer from the options given below: [29 Jan, 2023 (Shift-II)]
(a) B and E only (b) A and C only
(c) B, D and E only (d) B and D only

11. A force $F = (5 + 3y^2)$ acts on a particle in the y direction, where F is newton and y is in meter. The work done by the force during a displacement from $y = 2m$ to $y = 5m$ is _____. [1 Feb, 2023 (Shift-II)]

12. A lift of mass M = 500 kg is descending with speed of 2 ms^{-1}. Its supporting cable begins to slip thus allowing it to fall with a constant acceleration of 2 ms^{-2}. The kinetic energy of the lift at the end of the fall through to a distance of 6m will be _____ kJ. [31 Jan, 2023 (Shift-I)]

13. A small particle moves to position $5\hat{i} - 2\hat{j} + \hat{k}$ from its initial position $2\hat{i} + 3\hat{j} - 4\hat{k}$ under the action of force $5\hat{i} + 2\hat{j} + 7\hat{k}$ N. The value of work done will be J. [1 Feb, 2023 (Shift-I)]

14. A force $\vec{F} = (2 + 3x)\hat{i}$ acts on a particle in the x direction where F is in newton and x is in meter. The work done by this force during a displacement from $x = 0$ to $x = 4$ m, is _____ J. [11 April, 2023 (Shift-I)]

@MAKE_CBSE_EASY

6 Work, Power and Energy

Scan for Sol.

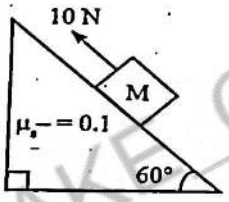
JEE-Main

Work Done by Constant Force, Variable Force, Kinetic Energy

1. Two bodies of mass 4g and 25g are moving with equal kinetic energies. The ratio of magnitude of their linear momentum is:
[27 Jan, 2024 (Shift-I)]
(a) 3 : 5 (b) 5 : 4 (c) 2 : 5 (d) 4 : 5

2. A block of mass 100kg slides over a distance of 10 m on a horizontal surface. If the co-efficient of friction between the surface is 0.4, then the work done against friction (in J) is: [29 Jan, 2024 (Shift-I)]
(a) 4200 (b) 3900 (c) 4000 (d) 4500

3. A block of mass 1 kg is pushed up a surface inclined to horizontal at an angle of 60° by a force of 10 N parallel to the inclined surface as shown in figure. When the block is pushed up by 10 m along inclined surface, the work done against frictional force is: [g = 10 m/s²]
[30 Jan, 2024 (Shift-II)]



(a) $5\sqrt{3}$ J (b) 5 J (c) 5×10^3 J (d) 10 J

4. An artillery piece of mass M_1 fires a shell of mass M_2 horizontally. Instantaneously after the firing, the ratio of kinetic energy of the artillery and that of the shell is: [31 Jan, 2024 (Shift-I)]
(a) $M_1/(M_1 + M_2)$ (b) $\frac{M_2}{M_1}$
(c) $M_2/(M_1 + M_2)$ (d) $\frac{M_1}{M_2}$

5. A bullet of mass 50 g is fired with a speed 100 m/s on a plywood and emerges with 40 m/s. The percentage loss of kinetic energy is:
[06 April, 2024 (Shift-I)]
(a) 32% (b) 44% (c) 16% (d) 84%

6. Four particles A, B, C, D of mass m/2, m, 2m, 4m, have same momentum, respectively. The particle with maximum kinetic energy is:
[06 April, 2024 (Shift-I)]
(a) D (b) C (c) A (d) B

7. When kinetic energy of a body becomes 36 times of its original value, the percentage increase in the momentum of the body will be:
[06 April, 2024 (Shift-II)]
(a) 500% (b) 600% (c) 6% (d) 60%

8. Three bodies A, B and C have equal kinetic energies and their masses are 400 g, 1.2 kg and 1.6 kg respectively. The ratio of their linear momenta is:
[08 April, 2024 (Shift-I)]
(a) $1 : \sqrt{3} : 2$ (b) $1 : \sqrt{3} : \sqrt{2}$
(c) $\sqrt{2} : \sqrt{3} : 1$ (d) $\sqrt{3} : \sqrt{2} : 1$

9. A force $(3x^2 + 2x - 5)$ N displaces a body from $x = 2$ m to $x = 4$ m. Work done by this force is ..... J.
[09 April, 2024 (Shift-II)]

10. Identify the correct statements from the following:
A. Work done by a person in lifting a bucket out of a well by means of a rope tied to the bucket is negative.
B. Work done by gravitational force in lifting a bucket out of a well by a rope tied to the bucket is negative.
C. Work done by friction on a body sliding down an inclined plane is positive.
D. Work done by an applied force on a body moving on a rough horizontal plane with uniform velocity is zero.
E. Work done by the air resistance on an oscillating pendulum is negative.
Choose the correct answer from the options given below:
[29 Jan, 2023 (Shift-II)]
(a) B and E only (b) A and C only
(c) B, D and E only (d) B and D only

11. A force $F = (5 + 3y^2)$ acts on a particle in the y direction, where F is newton and y is in meter. The work done by the force during a displacement from $y = 2m$ to $y = 5m$ is _____.
[1 Feb, 2023 (Shift-II)]

12. A lift of mass M = 500 kg is descending with speed of 2 ms^{-1}. Its supporting cable begins to slip thus allowing it to fall with a constant acceleration of 2 ms^{-2}. The kinetic energy of the lift at the end of the fall through to a distance of 6m will be _____ kJ.
[31 Jan, 2023 (Shift-I)]

13. A small particle moves to position $5\hat{i} - 2\hat{j} + \hat{k}$ from its initial position $2\hat{i} + 3\hat{j} - 4\hat{k}$ under the action of force $5\hat{i} + 2\hat{j} + 7\hat{k}$ N. The value of work done will be J.
[1 Feb, 2023 (Shift-I)]

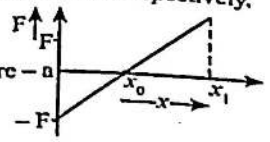
14. A force $\vec{F} = (2 + 3x)\hat{i}$ acts on a particle in the x direction where F is in newton and x is in meter. The work done by this force during a displacement from $x = 0$ to $x = 4$ m, is _____ J.
[11 April, 2023 (Shift-I)]

MAKE CBSE X @M_EDUME

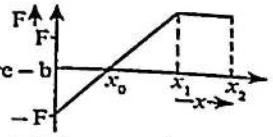
15. A block of mass 10 kg is moving along x-axis under the action of force $F = 5xN$. The work done by the force in moving the block from $x = 2\ m$ to 4 m will be _____ J. **[15 April, 2023 (Shift-I)]**

16. Arrange the four graphs in descending order of total work done; where W_1, W_2, W_3, and W_4, are the work done corresponding to figure A, B, C and d respectively. **[26 June, 2022 (Shift-II)]**

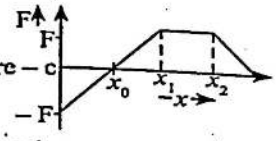
(A) Figure – a



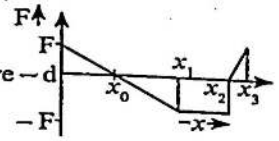
(B) Figure – b



(C) Figure – c



(D) Figure – d

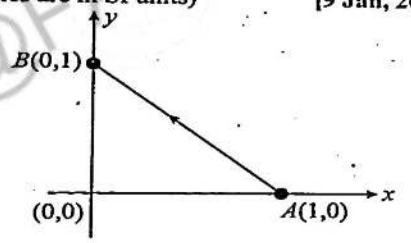


(a) $W_3 > W_2 > W_1 > W_4$ (b) $W_3 > W_2 > W_4 > W_1$
(c) $W_2 > W_3 > W_4 > W_1$ (d) $W_2 > W_3 > W_1 > W_4$

17. A force of $F = (5y + 20)\hat{j}N$ acts on a particle. The work done by this force when the particle is moved from $y = 0m$ to $y = 10\ m$ is _____ J. **[25 July, 2021 (Shift-II)]**

18. Two persons A and B perform same amount of work in moving a body through a certain distance d with application of forces acting at angle 45° and 60° with the direction of displacement respectively. The ratio of force applied by person A to the force applied by person B is $\frac{1}{\sqrt{x}}$. The value of x is _____. **[27 Aug, 2021 (Shift-I)]**

19. Consider a force $\vec{F} = -x\hat{i} + y\hat{j}$. The work done by this force in moving a particle from point $A(1,0)$ to $B(0,1)$ along the line segment is (All quantities are in SI units) **[9 Jan, 2020 (Shift-I)]**

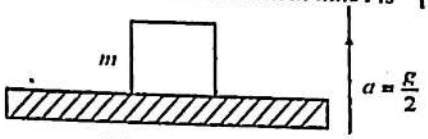


(a) $\frac{1}{2}$ (b) $\frac{3}{2}$ (c) 2 (d) 1

20. A person pushes a box on a rough horizontal platform surface. He applies a force of 200 N over a distance of 15 m. Thereafter, he gets progressively tired and his applied force reduces linearly with distance to 100 N. The total distance through which the box has been moved is 30m. What is the work done by the person during the total movement of the box? **[4 Sep, 2020 (Shift-II)]**

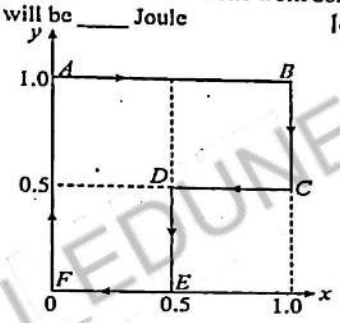
(a) 5690 J (b) 3280 J (c) 5250 J (d) 2780 J

21. A block of mass m is kept on a platform which starts from rest with constant acceleration $g/2$ upward, as shown in figure. Work done by normal reaction on block in time t is **[10 Jan, 2019 (Shift-I)]**



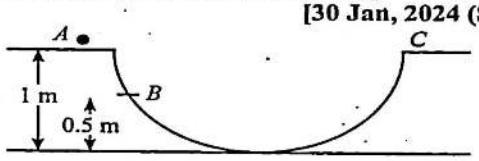
(a) $-\frac{mg^2t^2}{8}$ (b) $\frac{mg^2t^2}{8}$ (c) 0 (d) $\frac{3mg^2t^2}{8}$

22. A particle is moved along a path AB-BC-CD-DE-EF-FA, as shown in figure, in presence of a force $\vec{F} = (\alpha y\hat{i} + 2\alpha x\hat{j})$ N where x and y are in meter and $\alpha = -1$ N/m^{-1}. The work done on the particle by this force $\vec{F}$ will be _____ Joule **[JEE Adv, 2019]**



Work Energy Theorem, Mechanical Energy Conservation

23. A particle is placed at the point A of a frictionless track ABC as shown in figure. It is gently pushed toward right. The speed of the particle when it reaches the point B is : (Take $g = 10$ m/s^2). **[30 Jan, 2024 (Shift-I)]**

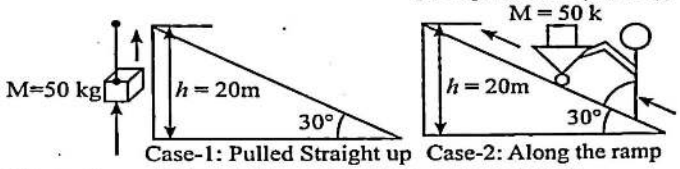


(a) 20 m/s (b) $\sqrt{10}$ m/s (c) $2\sqrt{10}$ m/s (d) 10 m/s

24. If a rubber ball falls from a height h and rebounds upto the height of $h/2$. The percentage loss of total energy of the initial system as well as velocity of ball before it strikes the ground, respectively, are: **[04 April, 2024 (Shift-I)]**

(a) 50%, $\sqrt{\frac{gh}{2}}$ (b) 50%, $\sqrt{gh}$ (c) 40%, $\sqrt{2gh}$ (d) 50%, $\sqrt{2gh}$

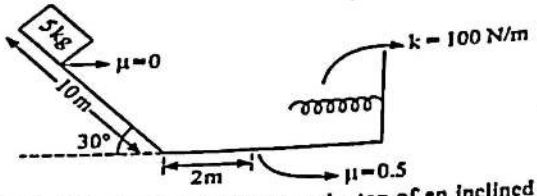
25. A body of mass 50 kg is lifted to a height of 20 m from the ground in the two different ways as shown in the figures. The ratio of work done against the gravity in both the respective cases, will be: **[05 April, 2024 (Shift-I)]**



Case-1: Pulled Straight up Case-2: Along the ramp

(a) 1 : 1 (b) 2 : 1 (c) 3 : 2 (d) 1 : 2

@FREE_BOOK@RAJEDUNET

26. 

A block is simply released from the top of an inclined plane as shown in the figure above. The maximum compression in the spring when the block hits the spring is: [08 April, 2024 (Shift-II)]

(a) $\sqrt{6}$ m (b) 2 m (c) 1 m (d) $\sqrt{5}$ m

27. A particle of mass m moves on a straight line with its velocity increasing with distance according to the equation $v = \alpha\sqrt{x}$, where α is a constant. The total work done by all the forces applied on the particle during its displacement from $x = 0$ to $x = d$, will be: [09 April, 2024 (Shift-I)]

(a) $\frac{m}{2\alpha^2 d}$ (b) $\frac{md}{2\alpha^2}$ (c) $\frac{m\alpha^2 d}{2}$ (d) $2m\alpha^2 d$

28. A 0.4 kg mass takes 8s to reach ground when dropped from a certain height 'P' above surface of earth. The loss of potential energy in the last second of fall is _____ J. [Take g = 10 m/s²] [29 Jan, 2023 (Shift-I)]

29. A car accelerates from rest to u m/s. The energy spent in this process is EJ. The energy required to accelerate the car from u m/s to 2u m/s is nEJ. The value of n is _____. [13 April, 2023 (Shift-II)]

30. A particle of mass 10g moves in a straight line with retardation $2x$, where x is the displacement in SI units. Its loss of kinetic energy for above displacement is $\left(\frac{10}{x}\right)^{-n}$ J.

The value of n will be _____. [6 April, 2023 (Shift-I)]

31. Given below are two statements:

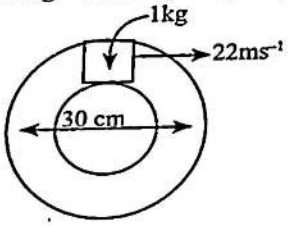
Statement-I: A truck and a car moving with same kinetic energy are brought to rest by applying brakes which provide equal retarding forces. Both come to rest in equal distance.

Statement-II: A car moving towards east takes a turn and moves towards north, the speed remains unchanged. The acceleration of the car is zero.

In the light of given statements, choose the most appropriate answer from the options given below. [12 April, 2023 (Shift-I)]

(a) Statement-I is correct but Statement-II is incorrect
(b) Statement-I is incorrect but Statement-II is correct
(c) Both Statement-I and Statement-II are incorrect
(d) Both Statement-I and Statement-II are correct

32. A closed circular tube of average radius 15 cm, whose inner walls are rough, is kept in vertical plane. A block of mass 1 kg just fit inside the tube. The speed of block is 22 m/s, when it is introduced at the top of tube. After completing five oscillations, the block stops at the bottom region of tube. The work done by the tube on the block _____ is J. [Given g = 10 m/s²] [10 April, 2023 (Shift-I)]



33. To maintain a speed of 80 km/h by a bus of mass 500 kg on a plane rough road for 4 km distance, the work done by the engine of the bus will be _____ KJ. [The coefficient of friction between tyre of bus and road is 0.04]. [12 April, 2023 (Shift-I)]

34. A body is dropped on ground from a height 'h_1' and after hitting the ground, it rebounds to a height 'h_2'. If the ratio of velocities of the body just before and after hitting ground is 4, then percentage loss in kinetic energy of the body is $\frac{x}{4}$. The value of x is [6 April, 2023 (Shift-II)]

35. A body of mass 0.5 kg travels on straight line path velocity $v = (3x^1 + 4)$ m/s. The net work done by the force during its displacement from $x = 0$ to $x = 2$m is: [25 July, 2022 (Shift-I)]

(a) 64 J (b) 60 J
(c) 120 J (d) 128 J

36. A particle of mass 500 gm is moving in a straight line with velocity $v = bx^{3/2}$. The work done by the net force during its displacement from $x = 0$ to $x = 4$ m is (Take: $b = 0.25$ m$^{-3/2}$ s^{-1}) [29 June, 2022 (Shift-I)]

(a) 2 J (b) 4 J (c) 8 J (d) 16 J

37. As per the given figure, two blocks each of mass 250g are connected to a spring of spring constant 2Nm^{-1}. If both are given velocity v in opposite directions, then maximum elongation of the spring is: [26 July, 2022 (Shift-I)]

(a) $\frac{v}{2\sqrt{2}}$ (b) $\frac{v}{2}$
(c) $\frac{v}{4}$ (d) $\frac{v}{\sqrt{2}}$

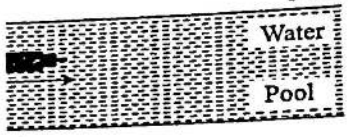
38. If momentum of a body is increased by 20%, then its kinetic energy increases by [29 July, 2022 (Shift-II)]

(a) 36 % (b) 40 % (c) 44 % (d) 48 %

39. A block of mass 2 kg moving on a horizontal surface with speed of 4 ms^{-1} enters a rough surface ranging from $x = 0.5$ m to $x = 1.5$ m. The retarding force in this range of rough surface is related to distance by $F = -kx$, where $k = 12$ Nm^{-1}. The speed of the block as it just crosses the rough surface will be: [28 June, 2022 (Shift-II)]

(a) zero (b) 1.5 ms^{-1}
(c) 2.0 ms^{-1} (d) 2.5 ms^{-1}

40. A bullet of mass 200g having initial kinetic energy 90 J is shot inside a long swimming pool as shown in the figure. If it's kinetic energy reduces to 40 J within 1s, the minimum length of the pool the bullet has to travel so that it completely comes to rest is [28 July, 2022 (Shift-II)]



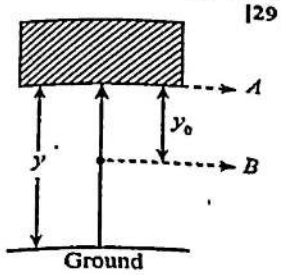
(a) 45 m (b) 90 m
(c) 125 m (d) 25 m

41. A particle experiences a variable force $\vec{F} = (4x\hat{i} + 3y^2\hat{j})$ in horizontal x–y plane. Assume distance in meters and force in Newton. If the particle moves from point (1, 2) to point (2, 3) in the x–y plane, then kinetic Energy changes by: [24 June, 2022 (Shift-I)]

(a) 50.0 J (b) 12.5 J
(c) 25.0 J (d) 0 J

JEE_BSEX @RAJ_EDUCATION

42. In the given figure, the block of mass m is dropped from the point 'A'. The expression for kinetic energy of block when it reaches point 'B' is: [29 June, 2022 (Shift-II)]

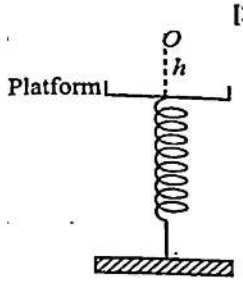


(a) $\frac{1}{2}mgy_0^2$ (b) $\frac{1}{2}mgy^2$

(c) $mg(y-y_0)$ (d) mgy_0

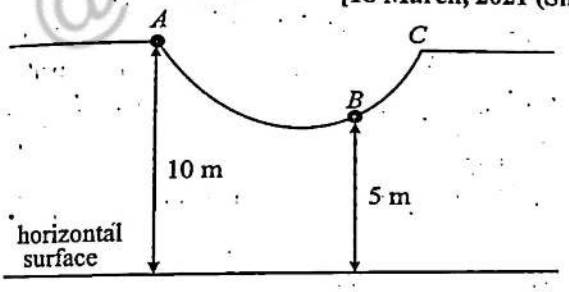
43. A 0.5 kg block moving at a speed of 12 ms^{-1} compresses a spring through a distance 30 cm when its speed is halved. The spring constant of the spring will be _____ Nm^{-1}. [25 June, 2022 (Shift-I)]

44. A ball of mass 100 g is dropped from a height $h = 10$ cm on a platform fixed at the top of a vertical spring (as shown in figure). The ball stays on the platform and the platform is depressed by a distance $h/2$. The spring constant is _____ Nm^{-1}. (Use $g = 10\ ms^{-2}$) [24 June, 2022 (Shift-I)]



45. A ball of mass 4 kg, moving with a velocity of 10 ms^{-1}, collides with a spring of length 8m and force constant 100 Nm^{-1}. The length of the compressed spring is x m. The value of x, to the nearest integer, is_____. [18 March, 2021 (Shift-II)]

46. As shown in the figure, a particle of mass 10 kg is placed at a point A. When the particle is slightly displaced to its right, it starts moving and reaches the point B. The speed of the particle at B is x m/s. The value of 'x' to the nearest integer is (Take $g = 10\ m/s^2$) [18 March, 2021 (Shift-I)]

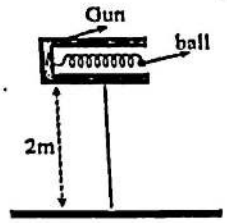


47. A body of mass 'm' dropped from a height 'h' reaches the ground with a speed of $0.8\sqrt{gh}$. The value of work done by the air-friction is: [1 Sep, 2021 (Shift-II)]

(a) –0.68 mgh (b) 0.64 mgh

(c) mgh (d) 1.64 mgh

48. In a spring gun having spring constant 100N/m a small ball 'B' of mass 100 g is put in its barrel (as shown in figure) by compressing the spring through 0.05 m. There should be a box placed at a distance 'd' on the ground so that the ball falls in it. If the ball leaves the gun horizontally at a height of 2 m above the ground . The value of d is _____m. [20 July, 2021 (Shift-I)]



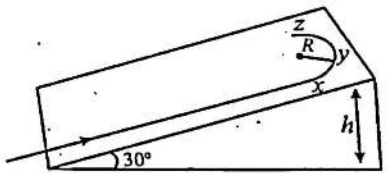
49. A uniform chain of length 3 meter and mass 3 kg overhangs a smooth table with 2 meter laying on the table. If k is the kinetic energy of the chain in joule as it completely slips off the table, then the value of k is (Take $g = 10\ m/s^2$) [26 Aug, 2021 (Shift-I)]

50. An engine is attached to a wagon through a shock absorber of length 1.5 m. The system with a total mass of 40,000 kg is moving with a speed of 72 kmh^{-1} when the brakes are applied to bring it to rest. In the process of the system being brought to rest, the spring of the shock absorber gets compressed by 1.0 m. If 90% of energy of the wagon is lost due to friction, the spring constant is _____ $\times 10^5$ N/m. [1 Sep, 2021 (Shift-II)]

51. A body of mass 2 kg is driven by an engine delivering a constant power of 1 J/s. The body starts from rest and moves in a straight line. After 9 seconds, the body has moved a distance (in m) _____. [5 Sep, 2020 (Shift-II)]

52. A cricket ball of mass 0.15 kg is thrown vertically up by a bowling machine so that it rises to a maximum height of 20 m after leaving the machine. If the part pushing the ball applies a constant force F on the ball and moves horizontally a distance of 0.2 m while launching the ball, the value of F (in N) is ($g = 10\ ms^{-2}$) _____. [3 Sep, 2020 (Shift-I)]

53. A student skates up a ramp that makes an angle 30° with the horizontal. He/she starts (as shown in the figure) at the bottom of the ramp with speed v_0 and wants to turn around over a semicircular path xyz of radius R during which he/she reaches a maximum height h (at point y) from the ground as shown in the figure. Assume that the energy loss is negligible and the force required for this turn at the highest point is provided by his/her weight only, then (g is the acceleration due to gravity) [JEE Adv, 2020]



(a) $v_0^2 - 2gh = \frac{1}{2}gR$

(b) $v_0^2 - 2gh = \frac{\sqrt{3}}{2}gR$

(c) The centripetal force required at points x and z is zero

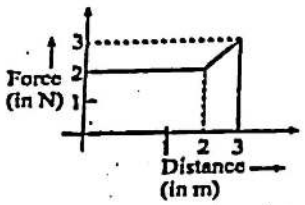
(d) The centripetal force required is maximum at points x and

@RACE_X@RALEDUCATION

54. A force acts on a 2 kg object so that its position is given as a function of time as $x = 3t^2 + 5$. What is the work done by this force in first 5 seconds? [9 Jan, 2019 (Shift-II)]

(a) 850 J (b) 950 J
(c) 875 J (d) 900 J

55. A particle moves in one dimension from rest under the influence of a force that varies with the distance travelled by the particle as shown in the figure. The kinetic energy of the particle after it has travelled 3 m is [8 April, 2019 (Shift-I)]



(a) 6.5 J (b) 2.5 J (c) 4 J (d) 5 J

56. A particle which is experiencing a force, given by $\vec{F} = 3\hat{i} - 12\hat{j}$, undergoes a displacement of $\vec{d} = 4\hat{i}$. If the particle had a kinetic energy of 3 J at the beginning of the displacement, what is its kinetic energy at the end of the displacement? [10 Jan, 2019 (Shift-II)]

(a) 9 J (b) 12 J (c) 10 J (d) 15 J

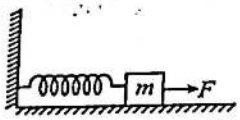
57. A wedge of mass $M = 4m$ lies on a frictionless plane. A particle of mass m approaches the wedge with speed v. There is no friction between the particle and the plane or between the particle and the wedge. The maximum height climbed by the particle on the wedge is given by: [9 April, 2019 (Shift-II)]

(a) $\frac{2v^2}{7g}$ (b) $\frac{v^2}{g}$ (c) $\frac{2v^2}{5g}$ (d) $\frac{v^2}{2g}$

58. A body of mass 1 kg falls freely from a height of 100 m, on a platform of mass 3 kg which is mounted on a spring having spring constant $k = 1.25 \times 10^6$ N/m. The body sticks to the platform and the spring's maximum compression is found to be x. Given that $g = 10\ ms^{-2}$, the value of x will be close to: [11 Jan, 2019 (Shift-I)]

(a) 40 cm (b) 4 cm (c) 80 cm (d) 8 cm

59. A block of mass m, lying on a smooth horizontal surface, is attached to a spring (of negligible mass) of spring constant k. The other end of the spring is fixed, as shown in the figure. The block is initially at rest in an equilibrium position. If now the block is pulled with a constant force F, the maximum speed of the block is [9 Jan, 2019 (Shift-I)]



(a) $\frac{2F}{\sqrt{mk}}$ (b) $\frac{F}{\pi\sqrt{mk}}$ (c) $\frac{\pi F}{\sqrt{mk}}$ (d) $\frac{F}{\sqrt{mk}}$

60. A uniform cable of mass 'M' and length 'L' is placed on a horizontal surface such that its $\left(\frac{1}{n}\right)^{th}$ part is hanging below the edge of the surface. To lift the hanging part of the cable upto the surface, the work done should be [9 April, 2019 (Shift-I)]

(a) $\frac{MgL}{n^2}$ (b) $\frac{MgL}{2n^2}$ (c) $\frac{2MgL}{n^2}$ (d) $nMgL$

61. A massless spring ($k = 800$ N/m), attached with a mass (500 g) is completely immersed in 1 kg of water. The spring is stretched by 2 cm and released so that it starts vibrating. What would be the order of magnitude of the change in the temperature of water when the vibrations stop completely? (Assume that the water container and spring receive negligible heat and specific heat of mass = 400 J/kg K, specific heat of water = 4184 J/kg K) [9 April, 2019 (Shift-II)]

(a) 10^{-3} K (b) 10^{-4} K (c) 10^{-1} K (d) 10^{-5} K

Power

62. A body of mass 2 kg begins to move under the action of a time dependent force given by $\vec{F} = (6t\hat{i} + 6t^2\hat{j})N$ The power developed by the force at the time t is given by: [31 Jan, 2024 (Shift-II)]

(a) $(6t^4 + 9t^3)$W (b) $(3t^3 + 6t^5)$W
(c) $(9t^3 + 6t^4)$W (d) $(9t^3 + 6t^5)$W

63. A body is moving unidirectionally under the influence of a constant power source. Its displacement in time t is proportional to: [05 April, 2024 (Shift-II)]

(a) t^2 (b) $t^{2/3}$ (c) $t^{3/2}$ (d) t

64. A body of mass 2 kg is initially at rest. It starts moving unidirectionally under the influence of a source of constant power P. Its displacement in 4s is $\frac{1}{3}\alpha^2\sqrt{P}$ m. The value of α will be [30 Jan, 2023 (Shift-II)]

65. The ratio of powers of two motors is $\frac{3\sqrt{x}}{\sqrt{x}+1}$, that are capable of raising 300 kg water in 5 minutes and 50 kg water in 2 minutes respectively from a well of 100 m deep. The value of x will be [13 April, 2023 (Shift-I)]

(a) 2 (b) 4 (c) 2.4 (d) 16

66. A body of mass 1 kg begins to move under the action of a time dependent force $\vec{F} = (t\hat{i} + 3t^2\hat{j})N$. where $\hat{i}$ and $\hat{j}$ are the unit vectors along x and y axis. The power developed by above force, at the time $t = 2s$. will be _____ W. [24 Jan, 2023 (Shift-II)]

67. A block of mass 5 kg starting from rest pulled up on a smooth incline plane making an angle of 30° with horizontal with an affective acceleration of 1 ms^{-2}. The power delivered by the pulling force at $t = 10$ s from the start is _____ W.
[Use $g = 10\ ms^{-2}$] (calculate the nearest integer value) [11 April, 2023 (Shift-II)]

68. If the maximum load carried by an elevator is 1400 kg(600 kg – Passenger + 800 kg – elevator), which is moving up with a uniform speed of 3ms^{-1} and the frictional force acting on it is 2000 N, then the maximum power used by the motor is _____ kW ($g = 10\ ms^2$). [10 April, 2023 (Shift-II)]

69. A particle of mass m is moving in a circular path of constant radius r such that its centripetal acceleration (a) is varying with time t as $a = k^2rt^2$, where k is a constant.
The power delivered to the particle by the force acting on it is given as [28 June, 2022 (Shift-I)]

(a) Zero (b) $mk^2r^2t^2$ (c) mk^2r^2t (d) mk^2rt

@PHYSICS @RAJ SIR

70. Sand is being dropped from a stationary dropper at a rate of 0.5 kgs^{-1} on a conveyor belt moving with a velocity of $5ms^{-1}$. The power needed to keep the belt moving with the same velocity will be:
[27 July, 2022 (Shift-I)]
(a) 1.25 W (b) 2.5 W (c) 6.25 W (d) 12.5 W

71. Water falls from a 40 m high dam at the rate of 9×10^4 kg per hour. Fifty percentage of gravitational potential energy can be converted into electrical energy. Using this hydro electric energy number of 100 W lamps, that can be lit, is:
(Take $g = 10\ ms^{-2}$)
[28 June, 2022 (Shift-II)]
(a) 25 (b) 50 (c) 100 (d) 18

72. A constant power delivering machine has towed a box, which was initially at rest, along a horizontal straight line. The distance moved by the box in time 't' is proportional to:
[18 March, 2021 (Shift-I)]
(a) $t^{1/2}$ (b) t (c) $t^{3/2}$ (d) $t^{2/3}$

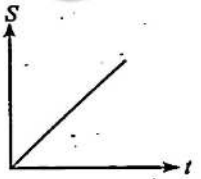
73. A body at rest is moved along a horizontal straight line by a machine delivering a constant power. The distance moved by the body in time 't' is proportional to:
[20 July, 2021 (Shift-II)]
(a) $t^{\frac{3}{4}}$ (b) $t^{\frac{3}{2}}$ (c) $t^{\frac{1}{2}}$ (d) $t^{\frac{1}{4}}$

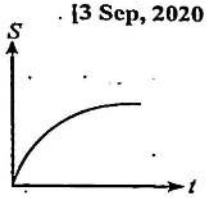
74. An automobile of mass 'm' accelerates starting from origin and initially at rest, while the engine supplies constant power P. The position is given as a function of time by :
[27 July, 2021 (Shift-II)]
(a) $\left(\frac{8P}{9m}\right)^{\frac{1}{2}} t^{\frac{3}{2}}$ (b) $\left(\frac{9P}{8m}\right)^{\frac{1}{2}} t^{\frac{3}{2}}$ (c) $\left(\frac{9m}{8P}\right)^{\frac{1}{2}} t^{\frac{3}{2}}$ (d) $\left(\frac{8P}{9m}\right)^{\frac{1}{2}} t^{\frac{2}{3}}$

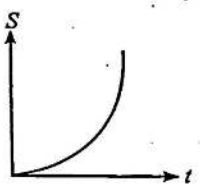
75. An elevator in a building can carry a maximum of 10 persons with the average mass of each person being 68 kg. The mass of the elevator itself is 920 kg and it moves with a constant speed of 3 m/s. The frictional force opposing the motion is 6000 N. If the elevator is moving up with its full capacity, the power delivered by the motor to the elevator must be at least ($g = 10\ m/s^2$)
[7 Jan, 2020 (Shift-II)]
(a) 62360 W (b) 56300 W (c) 48000 W (d) 66000 W

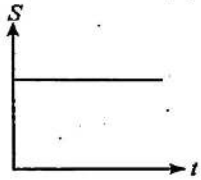
76. A 60 HP electric motor lifts an elevator having a maximum total load capacity of 2000 kg. If the frictional force on the elevator is 4000 N, the speed of the elevator at full load is close to : (1 HP = 746 W, $g = 10\ ms^{-2}$)
[7 Jan, 2020 (Shift-I)]
(a) 1.5 ms^{-1} (b) 1.9 ms^{-1} (c) 2.0 ms^{-1} (d) 1.7 ms^{-1}

77. A particle is moving unidirectionally on a horizontal plane under the action of a constant power supplying energy source. The displacement (s) - time (t) graph that describes the motion of the particle is (graphs are drawn schematically and are not to scale)
[3 Sep, 2020 (Shift-II)]

(a) 

(b) 

(c) 

(d) 

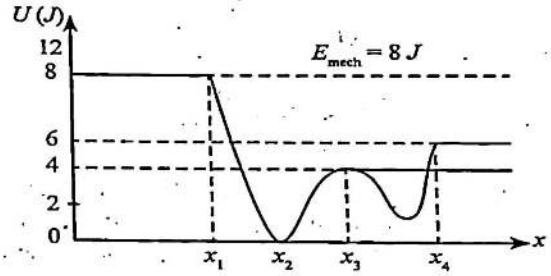
Potential Energy & Equilibrium

78. The potential energy function (in J) of a particle in a region of space is given as $U = (2x^2 + 3y^3 + 2z)$. [29 Jan, 2024 (Shift-I)]
Here x, y and z are in meter. The magnitude of x-component of force (in N) acting on the particle at point P (1, 2, 3) m is:
(a) 2 (b) 6
(c) 4 (d) 8

79. Potential energy as a function of r is given by, $U = \frac{A}{r^{10}} - \frac{B}{r^5}$, where r is the interatomic distance, A and B are positive constant. The equilibrium distance between the two atoms will be:
[24 June, 2022 (Shift-II)]
(a) $\left(\frac{A}{B}\right)^{\frac{1}{5}}$ (b) $\left(\frac{B}{A}\right)^{\frac{1}{5}}$
(c) $\left(\frac{2A}{B}\right)^{\frac{1}{5}}$ (d) $\left(\frac{B}{2A}\right)^{\frac{1}{5}}$

80. The potential energy of a particle of mass 4 kg in motion along the x-axis is given by $U = 4(1 - \cos 4x)$J. The time period of the particle for small oscillation ($\sin\theta \approx \theta$) is $\left(\frac{\pi}{K}\right)$ s. The value of K is _____.
[28 July, 2022 (Shift-II)]

81. Given below is the plot of a potential energy function $U(x)$ for a system, in which a particle is in one dimensional motion, while a conservation force $F(x)$ acts on it. Suppose that $E_{mech} = 8$ J, the incorrect statement for this system is: [27 July, 2021 (Shift-II)]
(a) at $x = x_3$, $K.E. = 4$ J.
(b) at $x > x_4$, $K.E.$ is constant throughout the region .
(c) at $x < x_1$, $K.E.$ is smallest and the particle is moving at the slowest speed.
(d) at $x = x_2$, $K.E.$ is greatest and the particle is moving at the fastest speed.



[where $K.E.$ = kinetic energy]

82. The potential energy (U) of a diatomic molecule is a function dependent on r (interatomic distance) as $U = \frac{\alpha}{r^{10}} - \frac{\beta}{r^5} - 3$
Where, α and β are positive constants. The equilibrium between two atoms will be $\left(\frac{2\alpha}{\beta}\right)^{\frac{a}{b}}$, where a = _____
[25 Feb, 2021 (Shift-I)]

@MKE-PRET@ONLINE.NET

Vertical Circular Motion

83. A ball suspended by a thread swings in a vertical plane so that its magnitude of acceleration in the extreme position and lowest position are equal. The angle (θ) of thread deflection in the extreme position will be: **[27 Jan, 2024 (Shift-II)]**

(a) $\tan^{-1}(\sqrt{2})$ (b) $2\tan^{-1}\left(\frac{1}{2}\right)$

(c) $\tan^{-1}\left(\frac{1}{2}\right)$ (d) $2\tan^{-1}\left(\frac{1}{\sqrt{5}}\right)$

84. A stone of mass 900g is tied to a string and moved in a vertical circle of radius 1m making 10 rpm. The tension in the string, when the stone is at the lowest point is (if $\pi^2 = 9.8$ and $g = 9.8$ m/s^2) **[29 Jan, 2024 (Shift-II)]**

(a) 97 N (b) 9.8 N

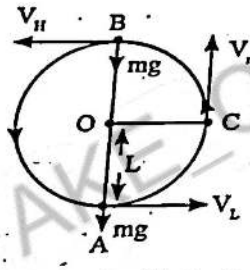
(c) 8.82 N (d) 17.8 N

85. The bob of a pendulum was released from a horizontal position. The length of the pendulum is 10m. If it dissipates 10% of its initial energy against air resistance, the speed with which the bob arrives at the lowest point is: [Use, g : 10 ms^{-2}] **[29 Jan, 2024 (Shift-II)]**

(a) $6\sqrt{5}$ ms^{-1} (b) $5\sqrt{6}$ ms^{-1}

(c) $5\sqrt{5}$ ms^{-1} (d) $2\sqrt{5}$ ms^{-1}

86. A bob of mass 'm' is suspended by a light string of length 'L'. It is imparted a minimum horizontal velocity at the lowest point A such that it just completes half circle reaching the top most position B. The ratio of kinetic energies $\frac{(K.E.)_A}{(K.E.)_B}$ is: **[29 Jan, 2024 (Shift-II)]**

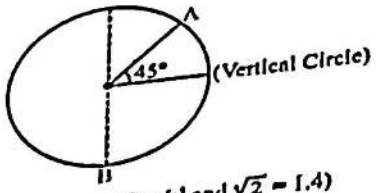


(a) 3 : 2 (b) 5 : 1 (c) 2 : 5 (d) 1 : 5

87. A simple pendulum of length 1 m has a wooden bob of mass 1 kg. It is struck by a bullet of mass 10^{-2} kg moving with a speed of 2×10^2 ms^{-1}. The bullet gets embedded into the bob. The height to which the bob rises before swinging back is. (use g = 10 m/s^2) **[1 Feb, 2024 (Shift-I)]**

(a) 0.30 m (b) 0.20 m (c) 0.35 m (d) 0.40 m

88. A body of m kg slides from rest along the curve of vertical circle from point A to B in friction less path. The velocity of the body at B is: **[04 April, 2024 (Shift-II)]**



(given, R = 14 m, g = 10 m/s^2 and $\sqrt{2} = 1.4$)

(a) 19.8 m/s (b) 21.9 m/s

(c) 16.7 m/s (d) 10.6 m/s

89. A stone of mass m, tied to a string is being whirled in a vertical circle with a uniform speed. The tension in the string is **[24 June, 2022 (Shift-I)]**

(a) The same throughout the motion

(b) Minimum at the highest position of the circle path

(c) Minimum at the lowest position of the circular path

(d) Minimum when the rope is the horizontal position

90. A stone tied to a string of length L is whirled in a vertical circle with the other end of the string at the centre. At a certain instant of time, the stone is at its lowest position and has a speed u. The magnitude of change in its velocity, as it reaches a position where the string is horizontal, is $\sqrt{x(u^2 - gL)}$. The value of x is **[27 June, 2022 (Shift-II)]**

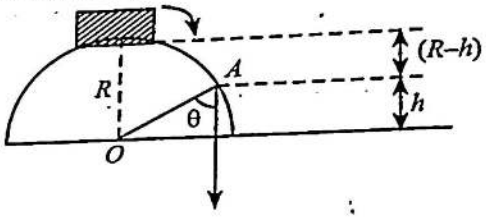
(a) 3 (b) 2 (c) 1 (d) 5

91. A pendulum of length 2 m consists of a wooden bob of mass 50 g. A bullet of mass 75 g is fired towards the stationary bob with a speed v. The bullet emerges out of the bob with a speed $v/3$ and the bob just completes the vertical circle. The value of v is _____ ms^{-1} ($g = 10$ m/s^2) **[27 June, 2022 (Shift-I)]**

92. A small bob tied at one end of a thin string of length 1m is describing a vertical circle so that the maximum and minimum tension in the string are in the ratio 5 : 1. The velocity of the bob at the highest position is _____ m/s. (Take $g = 10$ m/s^2) **[25 Feb, 2021 (Shift-I)]**

93. A small block slides down from the top of hemisphere of radius R = 3 m as shown in the figure. The height 'h' at which the block will lose contact with the surface of the sphere is _____ m. **[27 July, 2021 (Shift-II)]**

(Assume there is no friction between the block and the hemisphere)



@FAKE_CBSE_X@RAJ_EDUTECH

JEE-Advanced

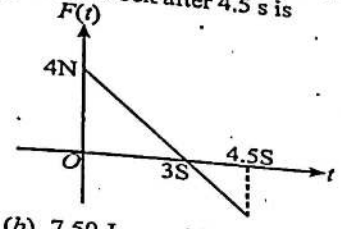
Work Done By Constant Force, Variable Force

Single Correct

1. The work done on a particle of mass m by a force, $K\left[\frac{x}{(x^2+y^2)^{3/2}}\hat{i}+\frac{y}{(x^2+y^2)^{3/2}}\hat{j}\right]$ (K being a constant of appropriate dimensions), when the particle is taken from the point $(a, 0)$ to the point $(0, a)$ along a circular path of radius a about the origin in the $x-y$ plane is **C-41.29 W-53.51 UA-5.2 (JEE Adv. 2013)**

(a) $\frac{2K\pi}{a}$ (b) $\frac{K\pi}{a}$ (c) $\frac{K\pi}{2a}$ (d) 0

2. A block of mass 2 kg is free to move along the x-axis. It is at rest and from $t = 0$ onwards it is subjected to a time-dependent force $F(t)$ in the x-direction. The force $F(t)$ varies with t as shown in the figure. The kinetic energy of the block after 4.5 s is **(IIT-JEE 2010)**



(a) 4.50 J (b) 7.50 J (c) 5.06 J (d) 14.06 J

3. A force $F = -k(y\hat{i} + x\hat{j})$ (where, k is a positive constant) acts on a particle moving in the $x-y$ plane. Starting from the origin, the particle is taken along the positive X-axis to the point $(a, 0)$ and then parallel to the Y-axis to the point (a, a). The total work done by the force F on the particle is **(IIT-JEE 1998)**

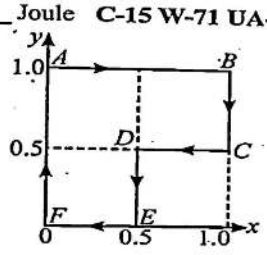
(a) $-2ka^2$ (b) $2ka^2$ (c) $-ka^2$ (d) ka^2

4. A uniform chain of length L and mass M is lying on a smooth table and one-third of its length is hanging vertically down over the edge of the table. If g is acceleration due to gravity, the work required to pull the hanging part onto the table is **(IIT-JEE 1985)**

(a) MgL (b) $MgL/3$ (c) $MgL/9$ (d) $MgL/18$

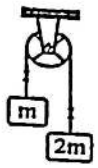
Numerical Types/Integer Types

5. A particle is moved along a path AB-BC-CD-DE-EF-FA, as shown in figure, in presence of a force $\vec{F} = (\alpha y\hat{i} + 2\alpha x\hat{j})$ N where x and y are in meter and $\alpha = -1$ N/m^{-1}. The work done on the particle by this force $\vec{F}$ will be ____ Joule **C-15 W-71 UA-14 (JEE Adv. 2019)**



Subjective

6. A light inextensible string that goes over a smooth fixed pulley as shown in the figure connects two blocks of masses 0.36 kg and 0.72 kg. Taking $g = 10$ ms^{-2}, find the work done (in Joule) by string on the block of mass 0.36 kg during the first second after the system is released from rest. **(IIT-JEE 2009)**

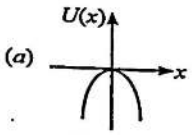


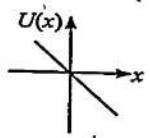
7. The displacement x of a particle moving in one dimension, under the action of a constant force is related to the time t by the equation $t = \sqrt{x} + 3$ where x is in metre and t in second. Find
(a) the displacement of the particle when its velocity is zero, and
(b) the work done by the force in the first 6 s. **(IIT-JEE 1980)**

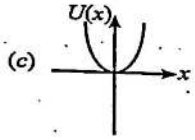
Potential Energy

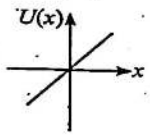
Single Correct

8. A particle is placed at the origin and a force $F = kx$ is acting on it (where, k is a positive constant). If $U(0) = 0$, the graph of $U(x)$ versus x will be (where, U is the potential energy function) **(IIT-JEE 2004)**

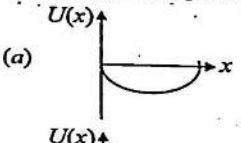
(a) 

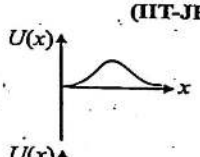
(b) 

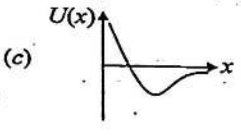
(c) 

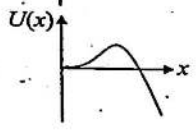
(d) 

9. A particle, which is constrained to move along x-axis, is subjected to a force in the same direction which varies with the distance x of the particle from the origin as $F(x) = -kx + ax^3$. Here, k and a are positive constants. For $x \geq 0$, the functional form of the potential energy $U(x)$ of the particle is **(IIT-JEE 2002)**

(a) 

(b) 

(c) 

(d) 

@FACEBOOK CRACKED UNIT

Match the Column

10. A particle of unit mass is moving along the x-axis under the influence of a force and its total energy is conserved. Four possible forms of the potential energy of the particle are given in Column-I (a and U_0 are constants). Match the potential energies in Column-I to the corresponding statements in Column-II **(JEE Adv. 2015)**

Column-I

A. $U_1(x)=\frac{U_0}{2}\left[1-\left(\frac{x}{a}\right)^2\right]^2$

B. $U_2(x)=\frac{U_0}{2}\left(\frac{x}{a}\right)^2$

C. $U_3(x)=\frac{U_0}{2}\left(\frac{x}{a}\right)^2\exp\left[-\left(\frac{x}{a}\right)^2\right]$

D. $U_4(x)=\frac{U_0}{2}\left[\frac{x}{a}-\frac{1}{3}\left(\frac{x}{a}\right)^3\right]$

Column-II

P. The force acting on the particle is zero at $x=a$

Q. The force acting on the particle is zero at $x=0$

R. The force acting on the particle is zero at $x=-a$

S. The particle experiences an attractive force towards $x=0$ in the region $|x|<a$

T. The particle with total energy $\frac{U_0}{4}$ can oscillate about the point $x=-a$

(a) (A)→(P, Q, T); (B)→(Q, T) (C)→(P, Q, R, S) (D)→(P, R, T)

(b) (A)→(P, Q, R, T) (B)→(Q, S) (C)→(P, Q, R) (D)→(P, R, T)

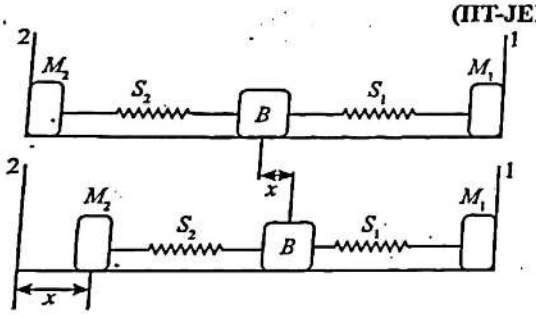
(c) (A)→(P, Q, R, T) (B)→(Q, S) (C)→(P, Q, R, S) (D)→(P, R, T)

(d) (A)→(P, Q, R, T) (B)→(Q, S)D (C)→(P, Q, S, T) (D)→(P, R, S)

Energy and Work-Energy Theorem

Single Correct

11. A block (B) is attached to two unstretched springs S_1 and S_2 with spring constants k and $4k$, respectively. The other ends are attached to two supports M_1 and M_2 not attached to the walls. The springs and supports have negligible mass. There is no friction anywhere. **(IIT-JEE 2008)**



The block B is displaced towards wall 1 by a small distance x and released. The block returns and moves a maximum distance y towards wall 2. Displacements x and y are measured with respect to the equilibrium position of the block B. The ratio $\frac{y}{x}$ is

(a) 4 (b) 2 (c) $\frac{1}{2}$ (d) $\frac{1}{4}$

12. **Statement-I:** A block of mass m starts moving on a rough horizontal surface with a velocity v. It stops due to friction between the block and the surface after moving through a certain distance. The surface is now tilted to an angle of 30° with the horizontal and the same block is made to go up on the surface with the same initial velocity v. The decrease in the mechanical energy in the second situation is smaller than that in the first situation.

Statement-II: The coefficient of friction between the block and the surface decreases with the increase in the angle of inclination. **(IIT-JEE 2007)**

(a) If Statement-I is true, Statement-II is true; Statement-II is the correct explanation for Statement-I

(b) If Statement-I is true, Statement-II is true; Statement-II is not a correct explanation for Statement-I

(c) If Statement-I is true; Statement-II is false

(d) If Statement-I is false; Statement-II is true

13. An ideal spring with spring constant k is hung from the ceiling and a block of mass M is attached to its lower end. The mass is released with the spring initially unstretched. Then the maximum extension in the spring is **(IIT-JEE 2002)**

(a) $\frac{4Mg}{k}$ (b) $\frac{2Mg}{k}$ (c) $\frac{Mg}{k}$ (d) $\frac{Mg}{2k}$

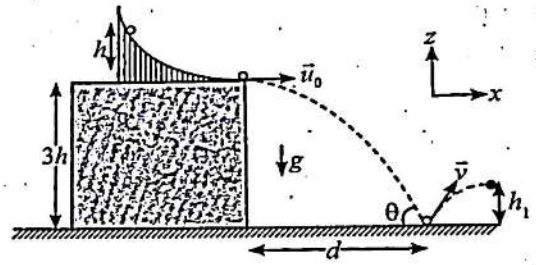
14. Two masses of 1 g and 4 g are moving with equal kinetic energies. The ratio of the magnitudes of their momenta is **(IIT-JEE 1980)**

(a) 4 : 1 (b) $\sqrt{2}$: 1 (c) 1 : 2 (d) 1 : 16

Multiple Correct

15. A slide with a frictionless curved surface, which becomes horizontal at its lower end, is fixed on the terrace of a building of height $3h$ from the ground, as shown in the figure. A spherical ball of mass m is released on the slide from rest at a height h from the top of the terrace. The ball leaves the slide with a velocity $\vec{u}_0=u_0\hat{x}$ and falls on the ground at a distance d from the building making an angle θ with the horizontal. It bounces off with a velocity $\vec{v}$ and reaches a maximum height h_1. The acceleration due to gravity is g and the coefficient of restitution of the ground is $\frac{1}{\sqrt{3}}$. Which of the following statements is/are correct?

C-11 W-12.56 UA-42.27 PC-34.16 (JEE Adv. 2023)



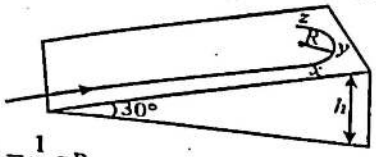
(a) $\vec{u}_0=\sqrt{2gh}\,\hat{x}$ (b) $\vec{v}=\sqrt{2gh}\,(\hat{x}-\hat{z})$

(c) $\theta=60°$ (d) $\frac{d}{h_1}=2\sqrt{3}$

@FAKE CBSE X @RAJEEV KIT

16. A student skates up a ramp that makes an angle 30° with the horizontal. He/she starts (as shown in the figure) at the bottom of the ramp with speed v_0 and wants to turn around over a semicircular path xyz of radius R during which he/she reaches a maximum height h (at point y) from the ground as shown in the figure. Assume that the energy loss is negligible and the force required for this turn at the highest point is provided by his/her weight only, then (g is the acceleration due to gravity)

C-12.76 W-35.23 UA-37.62 PC-14.39 (JEE Adv. 2020)



(a) $v_0^2 - 2gh = \frac{1}{2}gR$

(b) $v_0^2 - 2gh = \frac{\sqrt{3}}{2}gR$

(c) The centripetal force required at points x and z is zero

(d) The centripetal force required is maximum at points x and z

17. A particle of mass m is initially at rest at the origin. It is subjected to a force and starts moving along the X-axis. Its kinetic energy K changes with time as $dK/dt = \gamma t$, where γ is a positive constant of appropriate dimensions. Which of the following statements is (are) true? **C-8.49 W-27.19 UA-14.89 PC-49.42 (JEE Adv. 2018)**

(a) The force applied on the particle is constant

(b) The speed of the particle is proportional to time

(c) The distance of the particle from the origin increases linearly with time

(d) The force is conservative

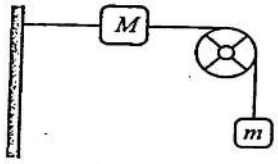
18. A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle. The motion of the particle takes place in a plane. It follows that **(IIT-JEE 1987)**

(a) Its velocity is constant (b) Its acceleration is constant

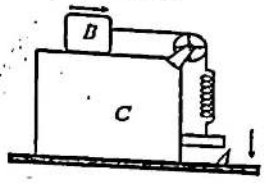
(c) Its kinetic energy is constant (d) It moves in a circular path

Subjective

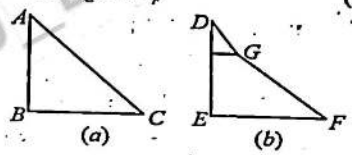
19. A string, with one end fixed on a rigid wall, passing over a fixed frictionless pulley at a distance of 2 m from the wall, has a point mass $M = 2$ kg attached to it at a distance of 1 m from the wall. A mass $m = 0.5$ kg attached at the free end is held at rest so that the string is horizontal between the wall and the pulley and vertical beyond the pulley. What will be the speed with which the mass M will hit the wall when the mass m is released? (Take $g = 9.8$ m/s²) **(IIT-JEE 1985)**



20. Two blocks A and B are connected to each other by a string and a spring; the string passes over a frictionless pulley as shown in the figure. Block B slides over the horizontal top surface of a stationary block C and the block A slides along the vertical side of C, both with the same uniform speed. The coefficient of friction between the surfaces of blocks is 0.2. Force constant of the spring is 1960 N/m. If mass of block A is 2 kg. Calculate the mass of block B and the energy stored in the spring. **(IIT-JEE 1982)**

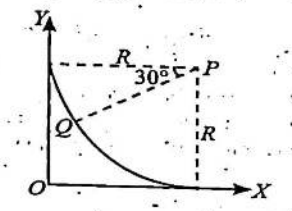


21. In the figures (a) and (b) AC, DG and GF are fixed inclined planes, $BC = EF = x$ and $AB = DE = y$. A small block of mass M is released from the point A. It slides down AC and reaches C with a speed v_C. The same block is released from rest from the point D. It slides down DGF and reaches the point F with speed v_F. The coefficients of kinetic frictions between the block and both the surfaces AC and DGF are μ. Calculate v_c and v_F **(IIT-JEE 1980)**



Passage Based Questions

Paragraph (Q. 22-23): A small block of mass 1 kg is released from rest at the top of a rough track. The track is a circular arc of radius 40 m. The block slides along the track without toppling and a frictional force acts on it in the direction opposite to the instantaneous velocity. The work done in overcoming the friction up to the point Q, as shown in the figure, is 150 J. (Take the acceleration due to gravity, $g = 10$ ms^{-2}) **(JEE Adv. 2013)**



22. The speed of the block when it reaches the point Q is

C-37.04 W-39.84 UA-23.12

(a) 5 ms^{-1} (b) 10 ms^{-1}

(c) $10\sqrt{3}$ ms^{-1} (d) 20 ms^{-1}

23. The magnitude of the normal reaction that acts on the block at the point Q is **C-32.93 W-36.42 UA-30.64**

(a) 7.5 N (b) 8.6 N

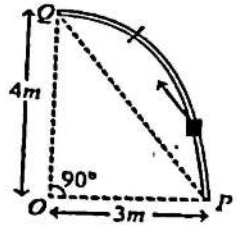
(c) 11.5 N (d) 22.5 N

@FAKE_CBSE_X @RAJ_EDUCART

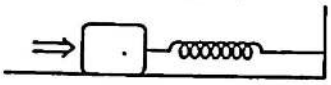
Numerical Types/Integer Types

24. Consider an elliptically shaped rail PQ in the vertical plane with $OP = 3\ m$ and $OQ = 4$ m. A block of mass 1 kg is pulled along the rail from P to Q with a force of 18 N, which is always parallel to line PQ (see figure). Assuming no frictional losses, the kinetic energy of the block when it reaches Q is $(n \times 10)$ J. The value of n is (take acceleration due to gravity = 10 ms^{-2})

C-30.08 W-61.51 UA-8.41 (JEE Adv. 2014)



25. A block of mass 0.18 kg is attached to a spring of force constant 2 n/m. The coefficient of friction between the block and the floor is 0.1. Initially the block is at rest and the spring is unstretched. An impulse is given to the block as shown in the figure. The block slides a distance of 0.06 m and comes to rest for the first time. The initial velocity of the block in m/s is $v = \frac{N}{10}$. Then N is (IIT-JEE 2011)



Fill in the Blanks

26. A cricket ball of mass 0.15 kg is thrown vertically up by a bowling machine, so that it rises to a maximum height of 20 m after leaving the machine. If the part pushing the ball applies a constant force F on the ball and moves horizontally a distance of 0.2 m, while launching the ball, the value of F (in N) is (Take, $g = 10\ ms^{-2}$) ..... .

(JEE Adv. 2015)

Power

Single Correct

27. A wind-powered generator converts wind energy into electric energy. Assume that the generator converts a fixed fraction of the wind energy intercepted by its blades into electrical energy. For wind speed v, the electrical power output will be proportional to (IIT-JEE 2000)

(a) v (b) v^2 (c) v^3 (d) v^4

28. A particle of mass m is moving in a circular path of constant radius r such that its centripetal acceleration a_c is varying with time t as $a_c = k^2rt^2$, where k is a constant. The power delivered to the particle by the force acting on it is (IIT-JEE 1994)

(a) $2\pi mk^2r^2$ (b) mk^2r^2t (c) $\frac{(mk^4r^2t^5)}{3}$ (d) Zero

9. A body is moved along a straight line by a machine delivering constant power. The distance moved by the body in time t is proportional to (IIT-JEE 1984)

(a) $t^{1/2}$ (b) $t^{3/4}$ (c) $t^{3/2}$ (d) t^2

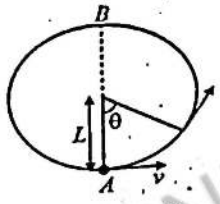
Numerical Types/Integer Types

30. A particle of mass 0.2 kg is moving in one dimension under a force that delivers a constant power 0.5 W to the particle. If the initial speed (in ms^{-1}) of the particle is zero, the speed (in ms^{-1}) after 5 s is (JEE Adv. 2013)

Vertical Circular Motion

Single Correct

31. A bob of mass M is suspended by a massless string of length L. The horizontal velocity v at position A is just sufficient to make it reach the point B. The angle θ at which the speed of the bob is half of that at A, satisfies (IIT-JEE 2008)



(a) $\theta = \frac{\pi}{4}$ (b) $\frac{\pi}{4} < \theta < \frac{\pi}{2}$

(c) $\frac{\pi}{2} < \theta < \frac{3\pi}{4}$ (d) $\frac{3\pi}{4} < \theta < \pi$

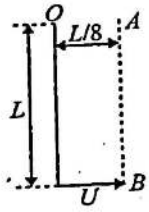
32. A stone tied to a string of length L is whirled in a vertical circle with the other end of the string at the center. At a certain instant of time, the stone is at its lowest position, and has a speed u. The magnitude of the change in its velocity as it reaches a position, where the string is horizontal, is (IIT-JEE 1998)

(a) $\sqrt{u^2 - 2gL}$ (b) $\sqrt{2gL}$

(c) $\sqrt{u^2 - gL}$ (d) $\sqrt{2(u^2 - gL)}$

Subjective

33. A particle is suspended vertically from a point O by an inextensible massless string of length L. A vertical line AB is at a distance $L/8$ from O as shown in figure. The object is given a horizontal velocity u. At some point, its motion ceases to be circular and eventually the object passes through the line AB. At the instant of crossing AB, its velocity is horizontal. Find u. (IIT-JEE 1999)



Numerical Types/Integer Types

34. A bob of mass m, suspended by a string of length l_1, is given a minimum velocity required to complete a full circle in the vertical plane. At the highest point, it collides elastically with another bob of mass m suspended by a string of length l_2, which is initially at rest. Both the strings are massless and inextensible. If the second bob, after collision acquires the minimum speed required to complete a full circle in the vertical plane, the ratio $\frac{l_1}{l_2}$ is

C-28.57 W-29.87 UA-41.56 (JEE Adv. 2013)

BREAKE_CBSE_@_MEDINET

ANSWER KEY

JEE-Main

1. (c)	2. (c)	3. (b)	4. (b)	5. (d)	6. (b)	7. (a)	8. (a)	9. (58)	10. (a)
11. [132]	12. [7]	13. [40]	14. [32]	15. [30]	16. (a)	17. [450]	18. [2]	19. (d)	20. (c)
21. (d)	22. [0.75]	23. (b)	24. (d)	25. (a)	26. (b)	27. (c)	28. [300]	29. [3]	30. [2]
31. (a)	32. [–245]	33. [784]	34. [375]	35. (b)	36. (d)	37. (b)	38. (c)	39. (c)	40. (a)
41. (c)	42. (c)	43. [600]	44. [120]	45. [2]	46. [10]	47. (a)	48. [1]	49. [40]	50. [16]
51. [18.00]	52. [150.00]	53. (a, d)	54. (d)	55. (a)	56. (d)	57. (c)	58. (*)	59. (d)	60. (b)
61. (d)	62. (d)	63. (c)	64. [4]	65. (d)	66. [100]	67. [300]	68. [48]	69. (c)	70. (d)
71. (b)	72. (c)	73. (b)	74. (a)	75. (d)	76. (b)	77. (c)	78. (c)	79. (c)	80. [2]
81. (c)	82. [1]	83. (b)	84. (b)	85. (a)	86. (b)	87. (b)	88. (b)	89. (b)	90. (b)
91. [10]	92. [5]	93. (b)							

JEE-Advanced

1. (d)	2. (c)	3. (c)	4. (d)	5. [0.75]	8. (a)	9. (d)	10. (c)	11. (c)	12. (c)
13. (b)	14. (c)	15. (a, c, d)	16. (a, d)	17. (a, b, d)	18. (c, d)	22. (b)	23. (a)	24. [5]	25. [4]
26. [150]	27. (c)	28. (b)	29. (c)	30. [5]	31. (d)	32. (d)	34. [5]		

EXPLANATIONS

JEE-Main

1. (c) As $p = \sqrt{2mk.E}$

$\Rightarrow \frac{P_1^2}{2m_1} = \frac{P_2^2}{2m_2} \Rightarrow \frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \frac{2}{5}$

2. (c) Given m = 100 kg

$s = 10$ m

$\mu = 0.4$

The force of friction

$f = \mu mg = 0.4 \times 100 \times 10 = 400$ N

Now the work done agninst friction

$W = f.s = 400 \times 10 = 4000$ J

3. (b) Given that, mass of the block = 1 kg

angle of inclination = 60°

Force = 10 N

Work done against frictional force

$= \mu N \times 10 = 0.1 \times 5 \times 10 = 5J$

4. (b) $|\overrightarrow{p_1}| = |\overrightarrow{p_2}|$

$KE = \frac{p^2}{2M}$; p same

$KE \propto \frac{1}{m}$

$\frac{KE_1}{KE_2} = \frac{p^2/2M_1}{p^2/2M_2} = \frac{M_2}{M_1}$

5. (d) Initial kinetic energy

$K_i = \frac{1}{2}m(100)^2$

Final kinetic energy

$K_f = \frac{1}{2}m(40)^2$

Percentage loss $= \frac{|K_f - K_i|}{K_i} \times 100$

$= \frac{\left|\frac{1}{2}m(40)^2 - \frac{1}{2}m(100)^2\right|}{\frac{1}{2}m(100)^2} \times 100\% = 84\%$

6. (b) $KE = \frac{1}{2}mv^2 = \frac{p^2}{2m}$

Momentum is same, so KE depends inversely on mass.

Therefore $\frac{M}{2}$ wiee have max K.E

7. (a) Kinetic energy (K) $= \frac{1}{2}$ mv²

$= \frac{P^2}{2m}$

$\therefore P = \sqrt{2mK}$

If $K_2 = 36\,K_1$

So, $P_2 = 6P_1$

$= \frac{P_2 - P_1}{P_1} \times 100\%$

Percentage increase in momentum

$= \frac{6P_1 - P_1}{P_1} \times 100\% = 500\%$.

8. (a) Here, kinetic energy $= \frac{P^2}{2m}$

[P is the momentum of the particle]

$P \propto \sqrt{m}$

Hence, $P_A : P_B : P_C$

$= \sqrt{400} : \sqrt{1200} : \sqrt{1600} = 1 : \sqrt{3} : 2$

9. (58) We have given,

$F = (3x^2 + 2x - 5)$N

$W = \int_{x_i}^{x_f} F dx$

$x_i = 2$m, $x_f = 4$m

$W = \int_2^4 \left(3x^2 + 2x - 5\right)dx$

$W = \left[x^3 + x^2 - 5x\right]_2^4$

W = [60 – 2]J = 58J

10. (a)

11. [132] $\because F = 5 + 3y^2$.

$\Rightarrow W = \int_2^5 \left(5 + 3y^2\right)dy = \left[5y + \frac{3y^3}{3}\right]_2^5$

$\therefore$ W = 132 J

12. [7] $\because v^2 = u^2 + 2as = 2^2 + 2\,(2)(6) = 28$

$\therefore KE = \frac{1}{2}mv^2$

$= \frac{1}{2}(500)28 = 7$ kJ

@FAKE_CBSE_X @RAJ_EDUNET

13. [40] $\because W = \vec{F} \times (\vec{r}_f - \vec{r}_i)$

$W = (5\hat{i}+2\hat{j}+7\hat{k}).\left((5\hat{i}-2\hat{j}+\hat{k}) - (2\hat{i}+3\hat{j}-4\hat{k})\right)$

$W = 40\ J$

14. [32] Formula of work done

$W = \int_{x_1}^{x_2} F(x).dx$

$W = \int_0^4 (2+3x)dx = \left[2x + \frac{3x^2}{2}\right]_0^4$

$= 8 + 3 \times 8 = 32\ J$

15. [30] Work done $W = \int_2^4 F dx$

$= \int_2^4 5x dx = 5\left[\frac{x^2}{2}\right]_2^4 = \frac{5}{2}[16-4] = 30J$

16. (a) Work done = area under F vs x diagram.

$\therefore W_3 > W_2 > W_1 > W_4$

17. [450] Work done by variable force.

$W = \int_0^{10} F_y dy \Rightarrow W = \int_0^{10} (5y+20)dy$

18. [2] According to the question, work done by person A = work done by person B.

$\Rightarrow F_A \times d \times \cos 45° = F_B \times d \times \cos 60°$

$\Rightarrow \frac{F_A}{F_B} = \frac{1}{\sqrt{2}} = \frac{1}{\sqrt{x}}$

$\Rightarrow x = 2$

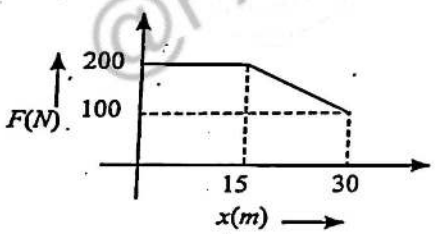
19. (d) $W = \int \vec{F}.d\vec{s}$

$= (-x\hat{i}+y\hat{j}).(dx\hat{i}+dy\hat{j})$

$= \int_1^0 -x dx + \int_0^1 y dy$

$= \frac{x^2}{2}\Big|_0^1 + \frac{y^2}{2}\Big|_0^1 = \left(0+\frac{1}{2}\right)+\left(\frac{1}{2}\right) = 1J$

20. (c)



Work = Area of F–x curve

$= 200 \times 15 + \frac{1}{2}(200+100) \times 15 = 5250\ J$

21. (d) $W = F s \cos\theta$

$= m\left(g+\frac{g}{2}\right) \times \left[\frac{1}{2} \times \frac{g}{2} \times t^2\right] = \frac{3}{8} mg^2 t^2$

22. [0.75] $\vec{F} = (\alpha y\hat{i} + 2\alpha x\hat{j})$

$W_{AB} = (-1\hat{i}).(1\hat{i}) = -1J$

$\left[\vec{F} = -1\hat{i} + 2\alpha x\hat{j}\right]$

$\left[\vec{S} = 1\hat{i}\right]$

Similarly,

$W_{BC} = 1J$

$W_{CD} = 0.25\ J$

$W_{DE} = 0.5\ J$

$W_{EF} = W_{FA} = 0.75\ J$

$\therefore$ New work in cycle = 0.75 J

23. (b) By Applying COME,

$KE_A + U_A = KE_B + U_B$

$0 + mg(1) = \frac{1}{2}mv^2 + mg \times 0.5$

$v = \sqrt{g} = \sqrt{10}$ m/s

24. (d) Velocity just before collision $= \sqrt{2gh}$

Velocity just after collision $= \sqrt{2g\left(\frac{h}{2}\right)}$

$\therefore \Delta KE = \frac{1}{2}m(2gh) - \frac{1}{2}mgh$

$= \frac{1}{2}mgh$

$\therefore$ % loss in energy $= \frac{\Delta KE}{KE_i} \times 100 = 0 = 50\%$

25. (a) The work done by the gravitational force, depends only on vertical displacement so work done in both cases will be same.

26. (b) Using work energy theorem, work done by all forces =change in kinetic energy,

$\Rightarrow w_g + w_{Fr} + w_s = \Delta KE$

$5 \times 10 \times 5 - 0.5 \times 5 \times 10 \times x - \frac{1}{2}Kx^2 = 0 - 0$

$2x^2 + x - 10 = 0$

$x = 2$

27. (c) Given;

$v = \alpha\sqrt{x}$

at $x = 0$: $v = 0$

& at $x = d$; $v = \alpha\sqrt{d}$

Now, W.D $= K_f - K_i$

$\Rightarrow$ W.D $= \frac{1}{2}m(\alpha\sqrt{d})^2 - \frac{1}{2}m(0)^2$

$\Rightarrow$ W.D $= \frac{m\alpha^2 d}{2}$

28. [300] Displacement in n^{th} sec is given by.

$S_{nth} = 4 + \frac{a}{2}(2n-1)$

$S_8 = 0 + \frac{1}{2} \times 10 \times (2 \times 8 - 1)$ $S_8 = 75m$

$\Delta U = 0.4 \times 10 \times 75$

$\Delta U = 300\ J$

29. [3] Energy spent $= E$

$\frac{1}{2}mu^2 - 0 = E \Rightarrow mu^2 = 2E$ ...(i)

Energy required $= nE$

$\frac{1}{2}m(2u)^2 - \frac{1}{2}mu^2 = nE$

$\frac{3}{2}mu^2 = nE$

$\frac{3}{2} \times 2E = nE$ [from (i)]

$n = 3$

30. [2] From work - energy theorem Loss of K.E = work done against retarding force

$= \int_0^x ma dx = \int_0^x m(2x)dx = mx^2$

$= (10 \times 10^{-3}\ kg)x^2\ J = \left(\frac{10}{x}\right)^{-2} J$

$\therefore n = 2$

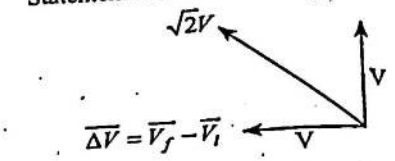
31. (a) Work done = change in kinetic energy

$-F.x = -K$

$x = \frac{K}{F}$

Statement I is correct

Statement II is incorrect



$\overrightarrow{\Delta V} = \overrightarrow{V_f} - \overrightarrow{V_i}$

Velocity is changing therefore, $\vec{a} \neq 0$

32. [–245] Using work energy theorem,

$W_f + W_g = \Delta KE$

$W_f + 10 \times 0.3 = -\frac{1}{2} \times 1 \times (22)^2$

$W_f = -245\ J$

33. [784] Form work - energy theorem

$W_{engine} + W_{friction} = 0$

$W_{engine} = -W_{friction} = -(-\mu mg\, x)$

$= 0.04 \times 500 \times 9.8 \times 4 \times 10^3$

$= 784$ kJ

34. [375] Let v_1 and v_2 are velocity just before and just after hitting the floor.

$\frac{v_1}{v_2} = 4 \Rightarrow v_2 = \frac{v_1}{4}$

$KE_1 = \frac{1}{2}mv_1^2$

@FAIZ_CBSE_RAJ_EDUNET

$$KE_2 = \frac{1}{2}mv_2^2 = \frac{1}{2}\frac{m \cdot v_1^2}{16}$$

$$\Delta KE = \frac{1}{2}mv_1^2\left(\frac{1}{16} - 1\right) = \frac{-15}{32}mv_1^2$$

$$\% \text{ loss in kinetic energy} = \frac{\Delta KE}{KE_1} \times 100\%$$

$$= \frac{-15}{16} \times 100 = \frac{-375}{4}\%$$

35. (*b*) At $x = 0$, $u = 3 \times (0)^2 + 4 = 4$ m/s
at $x = 2$m, $v = 3 \times 2^2 + 4 = 16$ m/s
From work-energy theorem.

$$W = \Delta k = \frac{1}{2}m[v^2 - u^2]$$

$$= \frac{1}{2} \times 0.5[16^2 - 4^2] = \frac{240}{4} = 60 \text{ J}$$

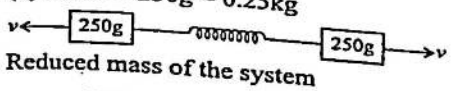
36. (*d*) By work energy theorem work done by net force = ΔK.E.

$$\Rightarrow W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$W = \frac{1}{2} \times 0.5 \times (0.25)^2 \times (4)^5$$

$$W = 16 \text{ J}$$

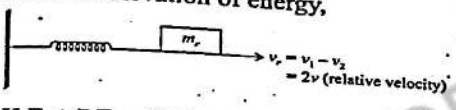
37. (*b*) Let $m = 250\text{g} = 0.25\text{kg}$



Reduced mass of the system

$$m_r = \frac{m_1 m_2}{m_1 + m_2} = \frac{mm}{m+m} = \frac{m}{2}$$

From conservation of energy,



$$\text{K.E}_i + \text{P.E}_i = \text{K.E}_f + \text{P.E}_f$$

$$\frac{1}{2}m_r v_r^2 + 0 = 0 + \frac{1}{2}kx^2$$

$$= \frac{1}{2} \times \frac{m}{2} \times 4v^2 = \frac{1}{2}kx^2$$

$$\frac{kx^2}{2} = mv^2$$

$$\frac{2}{2}x^2 = 0.25v^2$$

$$x = 0.5v$$

$$x = \frac{v}{2}$$

38. (*c*) $$\frac{\Delta K}{K_i} \times 100 = \frac{\frac{P_f^2}{2m} - \frac{P_i^2}{2m}}{\frac{P_i^2}{2m}} \times 100$$

$$\left[\because P = \sqrt{2M(KE)}\right]$$

$$= \frac{(1.2P_i)^2 - (P_i)^2}{P_i^2} \times 100 = 44\%$$

39. (*c*) Work done by retarding force = Change in kinetic energy

$$\Rightarrow \int_{x_i}^{x_f} -kx\,dx = \frac{1}{2}m[V_f^2 - V_i^2]$$

$$\Rightarrow \frac{-k}{2}[x_f^2 - x_i^2]_{0.5}^{1.5} = \frac{1}{2} \times 2[V_f^2 - 16]$$

$$[\because V_i = 4 \text{ m/s}]$$

$$\Rightarrow \frac{-12}{2}[1.5^2 - 0.5^2] = [V_f^2 - 16]$$

$$\Rightarrow -6[2 \times 1] = V_f^2 - 16$$

$$\Rightarrow v_f^2 = 16 - 12 = 4$$

$$\therefore v_f = 2 \text{ m/sec.}$$

40. (*a*) We know that,

$$P = mV = \sqrt{2mKE}$$

$$\therefore 0.2u = \sqrt{2 \times 0.2 \times 90}$$

$$\Rightarrow u = 30\text{m/s}$$

and $0.2v = \sqrt{2 \times 0.2 \times 40}$

$$\Rightarrow v = 20\text{m/s}$$

So, $a = \frac{v-u}{t} = \frac{20-30}{1} = \frac{-10ms^{-2}}{s^2}$

Now, using $x^2 - u^2 = 2aS$

$$\Rightarrow S = \frac{0 - 30^2}{2 \times (-10)} = 45m$$

41. (*c*) $\vec{F} = 4x\hat{i} + 3y^2\hat{j}$

$$d\vec{r} = d\vec{s} = dx\hat{i} + dy\hat{j}$$

$$W = \int \vec{F} \cdot d\vec{r}$$

$$= \int \left(4x\hat{i} + 3y^2\hat{j}\right) \cdot \left(dx\hat{i} + dy\hat{j}\right)$$

$$= \int_1^2 4x\,dx + \int_2^3 3y^2\,dy$$

$$= \frac{4}{2}\left[x^2\right]_1^2 + \frac{3}{3}\left[y^3\right]_2^3$$

$$= 2[4 - 1] + [27 - 8] = 6 + 19 = 25 \text{ J}$$

From work-energy theorm

$$\Delta K = W = 25 \text{ J}$$

42. (*c*) According to conservation of energy, we can write

Loss in potential energy = Gain in kinetic energy

$$U_{in} - U_f = K_f - K_{in}$$

$$mgy - mgy_0 = K_f - 0$$

$$K_f = mg(y - y_0)$$

43. [600] From conservation of energy,

$$U_i + K_i = U_f + K_f$$

$$\Rightarrow 0 + \frac{1}{2}m(12)^2 = \frac{1}{2}k(0.3)^2 + \frac{1}{2}m(6)^2$$

$$\Rightarrow 0.5(12^2 - 6^2) = k(0.3)^2$$

$$k = 600 \text{ N/m}$$

44. [120] Conservation of energy $\text{K.E}_1 + \text{P.E}_1 = \text{K.E}_2 + \text{P.E}_2$

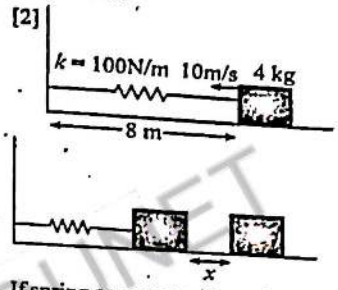
$$\Rightarrow 0 + mg\left(h + \frac{h}{2}\right) = 0 + \frac{1}{2}k\left(\frac{h}{2}\right)^2$$

$$\Rightarrow 3mgh = \frac{k}{4}h^2 \Rightarrow k = \frac{12mg}{h}$$

$$\Rightarrow k = \frac{12 \times 0.1 \times 10}{0.1}$$

$$k = 120 \text{ Nm}^{-1}$$

45. [2]



If spring compressed by x, then work done by spring $= 0 - \frac{1}{2} \times 4 \times 10^2$

Applying work energy theorem,

$$-\frac{1}{2}kx^2 = -\frac{1}{2} \times 4 \times 10^2$$

$$\Rightarrow 100x^2 = 4 \times 10^2 \Rightarrow x = 2$$

$\therefore$ Final length of the spring $= 8 - 2 = 6$ m

46. [10] By energy conservation $K_i + U_i = K_f + U_f$

$$0 + 10 \times 10 \times 10 = \frac{1}{2} \times 10 \times v_B^2 + 10 \times 10 \times 5$$

$$1000 = 5v_B^2 + 500$$

$$v_B^2 = \frac{500}{5} = 100$$

$$v_B = 10\text{m/s}$$

$$x = 10$$

47. (*a*) Work done = Change in K.E.

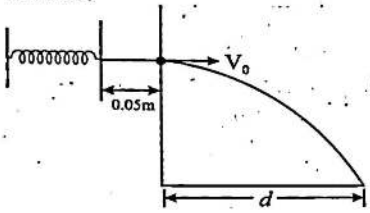
So $W_{mg} + W_2 = \frac{1}{2}M(0.8\sqrt{gh})^2 - 0$

[W_2 work done by air friction]

$$\Rightarrow W_2 = 0.32mgh - mgh = -0.68mgh$$

$$\therefore W_2 = -0.68mgh$$

48. [1] Let ball starts its motion with horizontal velocity v_0, so with the help of conservation of mechanical energy, we can write



@FAKE_CBSE_@RAJ_EDUNET

$\frac{1}{2}mv_0^2 = \frac{1}{2}kx^2 \Rightarrow v_0 = x\sqrt{\frac{k}{m}} = 0.05\times\sqrt{\frac{100}{0.1}}$

$= 0.5\times\sqrt{10}$ m/s

For vertical motion,

t = Time required to fall the ball

$= \sqrt{\frac{2h}{g}} = 2\times\sqrt{\frac{1}{10}}$ s

For horizontal motion,

$\Rightarrow d = v_0 \times t = 0.5\times\sqrt{10}\times 2\times\sqrt{\frac{1}{10}} = 1$m

49. [40] From the conservation of energy.

$[\lambda\times 3\times g]\times\frac{3}{2} - [\lambda\times 1\times g]\times\frac{1}{2} = K$

λ = Mass per unit length.

$\lambda g\left(\frac{9}{2}-\frac{1}{2}\right) = K \Rightarrow \frac{3}{3}\times 10\times 4 = K$

$K = 40\,J$

50. [16] Work done by friction + work done by spring

$= 0 - \frac{1}{2}mV^2$

[As 90% of K.E. is losed by friction]

$-\frac{90}{100}\left(\frac{1}{2}mV^2\right) - \frac{1}{2}Kx^2 = -\frac{1}{2}mV^2$

$-\frac{1}{2}kx^2 = \left(\frac{90}{100}-1\right)\frac{1}{2}mV^2 = \frac{-10}{100}\frac{1}{2}mV^2$

$-Kx^2 = -\frac{1}{10}mV^2$

$-K = -\frac{1}{10}\times\frac{40000\times 20^2}{1} = 4000\times 400$

$-K = -16\times 10^5 \Rightarrow K = 16\times 10^5$

51. [18.00] $pt = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2pt}{m}} \Rightarrow \frac{ds}{dt} = \sqrt{\frac{2pt}{m}}$

$\Rightarrow \int_0^s ds = \int_0^t \sqrt{\frac{2pt}{m}}dt \Rightarrow S = 18$m

52. [150.00] Initial velocity $v_0^2 = 2gh$

$\Rightarrow v_0 = \sqrt{2\times 10\times 20} = 20$ m/s

Now work done by the machine.

$Fx = \Delta KE = \frac{1}{2}mv_0^2$

$F\times\frac{2}{10} = \frac{1}{2}\times\frac{15}{100}\times 400$

$\Rightarrow F = 150N$

53. (*a, d*) By the energy conservation (ME) between bottom point and point '*y*'

$\frac{1}{2}mv_0^2 = mgh + \frac{1}{2}mv_1^2$

$\therefore v_1^2 = v_0^2 - 2gh$ ...(*i*)

Now at point '*y*' the centripetal force provided by the component of mg

$\therefore mg\sin 30° = \frac{mv_1^2}{R}$, $\therefore v_1^2 = \frac{gR}{2}$

$\therefore$ from (*i*)

$\frac{gR}{2} = v_0^2 - 2gh$

At point x and z of circular path, the points are at same height but less then h. So the velocity more than a point y.

So required centripetal $= \frac{mv^2}{r}$ is more.

54. (*d*) $x = 3t^2 + 5$

$v = 6t \Rightarrow \Delta W = \Delta K$

$= \frac{1}{2}(2)(30)^2 - \frac{1}{2}2(0)^2$

$= 900\,J$

55. (*a*) According to work energy theorem. Work done by force on the particle = Change in KE

Work done = Area under F-x graph

$\int F.dx$

$= 2\times 2 + \frac{(2+3)\times 1}{2}$

$W = KE_{final} - KE_{initial} = 6.5$

$KE_{initial} = 0$

$KE_{final} = 6.5\,J$

56. (*d*) $K.E. - 3 = \vec{F}\cdot\vec{d}$

$K.E. = 3 + (3\hat{i} - 12\hat{j})\times(4\hat{i})$

$K.E. = 3 + 12 = 15\,J$

57. (*c*) Using linear conservation of momentum:

$mv = (m+4m)v_f$ ...(*i*)

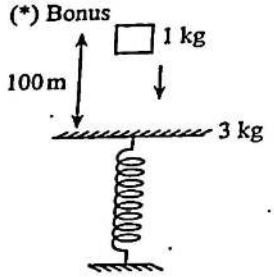
Using conservation of energy,

$\frac{1}{2}mv^2 = \frac{1}{2}(m+4m)v_f^2 + mgh$ ...(*ii*)

Using equation (*i*) and (*ii*)

$h = \frac{2v^2}{5g}$

58. (*) Bonus



$v = \sqrt{2\times 10\times 100} = 20\sqrt{5}$

Speed of block after collision

$v_p = \frac{1\times 20\sqrt{5}}{4} = 5\sqrt{5}$

Now using energy conservation,

$\frac{1}{2}\times 4\times(5\sqrt{5})^2 + \frac{1}{2}\times 1.25\times 10^4\left(\frac{30}{k}\right)^2$

$= -4\times 10\times\left(x - \frac{30}{k}\right) + \frac{1}{2}kx^2$

$\Rightarrow 250 + \frac{900}{2\times 1.25\times 10^4}$

$= -40x + \frac{1200}{k} + \frac{1}{2}kx^2$

$x \approx 2$ cm (Maximum compression in spring)

59. (*d*) When $v_{max} \Rightarrow$ acceleration $= 0$

$\Rightarrow x = \frac{F}{k}$

Applying work energy theorem

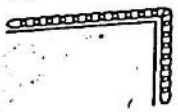
$W_{sp} + W_F = \Delta K.E.$

$-\frac{1}{2}kx^2 + F.x = \Delta K.E.;$

$-\frac{1}{2}k\frac{F^2}{k^2} + \frac{F^2}{k} = \frac{1}{2}mv_{max}^2$

$\frac{F^2}{2k} = \frac{1}{2}mv_{max}^2 \Rightarrow \frac{F}{\sqrt{mk}} = v_{max}$

60. (*b*) Mass of the hanging part $= \frac{M}{n}$



$h_{COM} = \frac{L}{2n}$

Work done, $W = mgh_{COM}$

$= \left(\frac{M}{n}\right)g\left(\frac{L}{2n}\right) = \frac{MgL}{2n^2}$

61. (*d*) By law of conservation of energy

$\frac{1}{2}kx^2 = (m_1s_1 + m_2s_2)\Delta T$

$\Delta T = \frac{16\times 10^{-2}}{4384} = 3.65\times 10^{-5}K$

62. (*d*) Force is given as,

$\vec{F} = (6t\hat{i} + 6t^2\hat{j})$N

$\vec{F} = ma = (6t\hat{i} + 6t^{2\hat{j}})$

$\vec{a} = \frac{\vec{F}}{m} = (3t\hat{i} + 3t^{2\hat{j}})$

Integrating acceleration with time t will give velocity,

$\vec{v} = \int_0^t \vec{a}dt = \frac{3t^2}{2}\hat{i} + t^{3\hat{j}}$

We know,

$P = \vec{F}\cdot\vec{v} = (9t^3 + 6t^5)$

@AKE_CBSE_X @RAJ_EDUNET

63. (c)

$\Rightarrow m\frac{dv}{dt}v =$ constant

$\int_0^v v dv = (C)\int_0^t dt \Rightarrow \left(\frac{v^2}{2}\right) = Ct$

$v \propto t^{1/2} \Rightarrow \frac{ds}{dt} \propto t^{1/2}$

$\int_0^s ds = K\int_0^t t^{1/2} dt \Rightarrow S = K \times \frac{2}{3} t^{3/2}$

$S \propto t^{3/2}$

64. [4] $\frac{1}{2}mv^2 = Pt$

$v = \sqrt{\frac{2Pt}{m}}$

$\frac{dx}{dt} = \sqrt{\frac{2Pt}{m}}$

$dx = \sqrt{\frac{2Pt}{m}} dt$

Integration both sides

$x = \sqrt{\frac{2P}{m}} \frac{2}{3} \left[t^{3/2}\right]_0^4$

$x = \frac{16\sqrt{P}}{3} = \frac{1}{3} \times 16\sqrt{P}$

$\because x = \frac{1}{3}\alpha^2\sqrt{P}$

$\Rightarrow \alpha = 4$

65. (d) Since, $P = \frac{mgh}{t}$

$\frac{P_1}{P_2} = \frac{\frac{m_1 gh}{t_1}}{\frac{m_2 gh}{t_2}} = \frac{m_1}{t_1}\frac{t_2}{m_2}$

$\frac{3\sqrt{x}}{\sqrt{x}+1} = \frac{300\times 2}{5\times 50} = \frac{12}{5}$

$12\sqrt{x} + 12 = 15\sqrt{x} \Rightarrow x = 16$

66. [100] $\vec{F} = t\hat{i} + 3t^2\hat{j}$

$\frac{m d\vec{v}}{dt} = t\hat{i} + 3t^2\hat{j}$

$m = 1\ kg,$

$\int_0^{\vec{v}} d\vec{v} = \int_0^t t dt\hat{i} + \int_0^t 3t^2 dt\hat{j}$

$\vec{v} = \frac{t^2}{2}\hat{i} + t^3\hat{j}$

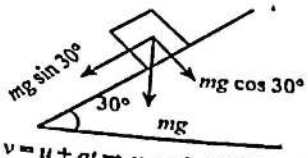
Power $= \vec{F}\cdot\vec{v} = \frac{t^3}{2} + 3t^5$

At $t = 2$s, power $= \frac{8}{2} + 3\times 32$

Power $= 100w$

67. [300] $F - 5g\sin 30° = 5a$

$\Rightarrow F = 5 + 25 = 30N$



$v = u + at \Rightarrow v_{10} = 0 + 1(10) = 10\ m/s$

$P = Fv = 300\ W$

68. [48] $P_{max} = F_{max} \times v$

$P_{max} = (1400\ g + \text{friction}) \times v$

$= (14000 + 2000) \times (3) = 48000$ w

$= 48$ kW

69. (c) Centripetal acceleration, $a = k^2 r t^2$

Since, centripetal acceleration is $\frac{v^2}{r}$

$\therefore \frac{v^2}{r} = k^2 r t^2$

$v = krt$

Centripetal force is perpendicular to the tangential velocity, therefore power delivered by it will be zero.

Tangential acceleration,

$\Rightarrow a_t = \frac{dv}{dt} = kr$

$\Rightarrow$ Tangential force, $F_t = ma_t = mkr$

$\therefore$ Power delivered, $P = F_t v = (mkr)(krt)$

$= mk^2 r^2 t$

70. (d) $P = \vec{F}\cdot\vec{v} = v\frac{dP}{dt} = v\cdot\frac{d}{dt}(mv)$

$= v^2\left(\frac{dm}{dt}\right) = 0.5\times 25 = 12.5W$

71. (b) If is given that, water flow rate, $m = 9\times 10^4$ kg/hr

$= \frac{9\times 10^4 \text{ kg/sec}}{60\times 60}$

$\therefore$ mgh $= \frac{9\times 10^4}{60\times 60}\times 10\times 40$

According to the question, mgh $= 10^4$ watt

It is given, 50% of it converts into electrical energy = 50% of mgh = $10^4/2$ watt

If n be the number of bulbs then,

$n\times 100 = \frac{10^4}{2}$

$\therefore\ n = 50$

72. (c) $\int_0^v v dv = \frac{P}{m}\int_0^t dt$

$\Rightarrow v = \left(\sqrt{\frac{2P}{m}}\right)t^{1/2} \Rightarrow v \propto t^{1/2}$

$\Rightarrow x \propto t^{3/2}\left(\because v = \frac{x}{t}\right)$

73. (b) According to question,

Power $= Fv = k \Rightarrow mv\frac{dv}{dt} = k$

$\Rightarrow \int_0^v v dv = \frac{k}{m}\int_0^t dt \Rightarrow \frac{v^2}{2} = \frac{k}{m}t$

$\Rightarrow v = \frac{dx}{dt} = \sqrt{\frac{2k}{m}}t^{\frac{1}{2}}$

$\Rightarrow \int_0^x dx = \sqrt{\frac{2k}{m}}\int_0^t t^{\frac{1}{2}} dt \Rightarrow x = \sqrt{\frac{2k}{m}}\left(\frac{t^{\frac{3}{2}}}{\frac{3}{2}}\right)$

$= \frac{2}{3}\sqrt{\frac{2k}{m}}\left(t^{\frac{3}{2}}\right) \Rightarrow x \propto \left(t^{\frac{3}{2}}\right)$

74. (a) Power, $P =$ constant

$P = Fv = mv\frac{dv}{dx}v$

$\frac{P}{m}\int dx = \int v^2 dv$

$\frac{Px}{m} = \frac{v^3}{3}$

$\left(\frac{3P}{m}x\right)^{1/3} = v = \frac{dx}{dt}$

$\left(\frac{3P}{m}\right)^{1/3}\int_0^t dt = \int_0^x x^{-1/3} dx$

$\Rightarrow x = \left(\frac{8P}{9m}\right)^{1/2} t^{3/2}$

75. (d) Net force on motor will be

$F_{min} = [920 + 68\ (10)]g + 6000 = 22000$ N

So, required power for motor

$P_{min} = \vec{F}_{min}\cdot\vec{v}$

$= 22000 \times 3 = 66000$ watt

76. (b) $4000 \times V + mg \times V = P$

$\frac{60\times 746}{4000+2000} = V$

$V = 1.86$ m/s. ≈ 1.9 m/s.

77. (c) $\frac{1}{2}mv^2 = p\times t$

$v \propto \sqrt{t} \Rightarrow \frac{ds}{dt} \propto \sqrt{t}$

$s \propto t^{3/2}$

78. (c) Given $U = 2x^2 + 3y^3 + 2z$ and $x = 1, y = 2, z = 3$

$F_x = -\frac{\partial U}{\partial x} = -4x$

At $x = 1$ magnitude of F_x is 4N

79. (c) At equilibrium,

$\frac{dU}{dr} = 0 \Rightarrow \frac{d}{dr}\left[\frac{A}{r^{10}}\right] - \frac{d}{dr}\left[\frac{B}{r^5}\right] = 0$

@FAKE_CBSE_@RAJ_EDUNET

$\Rightarrow -10Ar^{10-1} - B(-5)r^{5-1} = 0$

$\Rightarrow -10Ar^{11} + 5Br^4 = 0$

$10Ar^{11} = 5Br^4 \Rightarrow r^7 = \frac{2A}{B}$

$\therefore r = \left(\frac{2A}{B}\right)^{\frac{1}{7}}$

80. [2] *We have,* $m = 4kg$

$U = 4(1 - \cos 4x)J$

$F = \frac{-\partial U}{\partial x} = -4 \times 4\sin 4x$

$\therefore a = -\frac{16}{4}\sin 4x = -4\sin 4x = -16x$

$\Rightarrow \omega^2 = 16 \Rightarrow \omega = 4 = \frac{2\pi}{T}$

$\Rightarrow T = \frac{\pi}{2}\text{sec} \Rightarrow K = 2$

81. (*c*) $ME = PE + KE = 8J$

At x_3, $8 = KE + 4 \Rightarrow KE = 4J$

At x_2, $8 = KE + 0 \Rightarrow KE_{max} = 8J$

At $x < x_1$, $8 = KE + 8 \Rightarrow KE$ is 0

82. [1] For equilibrium, $\frac{dU}{dr} = 0$

Therefore, $\frac{-10\alpha}{r^{11}} + \frac{5\beta}{r^6} = 0 \Rightarrow r = \left(\frac{2\alpha}{\beta}\right)^{\frac{1}{5}}$

83. (*b*) According to conservation of energy

$\Rightarrow \frac{1}{2}mv^2 = mg\ell(1 - \cos\theta)$

$\Rightarrow \frac{v^2}{\ell} = 2g(1 - \cos\theta)$

Acceleration at extreme point = g sinθ

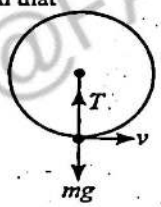
Acceleration at lowest point = $\frac{v^2}{\ell}$

Hence, $\frac{v^2}{\ell} = g\sin\theta$

$\therefore \sin\theta = 2(1 - \cos\theta)$

$\Rightarrow \tan\frac{\theta}{2} = \frac{1}{2} \Rightarrow \theta = 2\tan^{-1}\left(\frac{1}{2}\right)$

84. (*b*) Given that



$m = 900\text{ gm} = \frac{900}{1000}\text{kg} = \frac{9}{10}\text{kg}$

$r = 1\text{ m}$

$\omega = \frac{2\pi N}{60} = \frac{2\pi(10)}{60} = \frac{\pi}{3}\text{rad/sec}$

The tension in the string,

$T - mg = mr\omega,\ T = mg + mr\omega^2$

$= \frac{9}{10} \times 9.8 + \frac{9}{10} \times 1\left(\frac{\pi}{3}\right)^2 = 8.82 + 0.98$

$= 9.80\text{ N}$

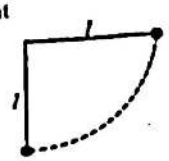
85. (*a*) $l = 10$ m.

Intial energy = mgl

So, $\frac{9}{10}mgl = \frac{1}{2}mv^2$

$\Rightarrow \frac{9}{10} \times 10 \times 10 = \frac{1}{2}v^2$

The speed with the bob arrives at the lowest point



$v^2 = 180,\ v = 6\sqrt{5}$ m/s

86. (*b*) Apply energy conservation between *A* and *B*

$\frac{1}{2}mV_L^2 = \frac{1}{2}mV_H^2 + mg(2L)$

$\because V_L = \sqrt{5gL}$

So, $V_H = \sqrt{gL}$

The ratio of kinetic energies

$\frac{(K.E)_A}{(K.E)_B} = \frac{\frac{1}{2}m\left(\sqrt{5gL}\right)^2}{\frac{1}{2}m\left(\sqrt{gL}\right)^2} = \frac{5}{1}$

87. (*b*) Applying principle of conservation of linear momentum, we get

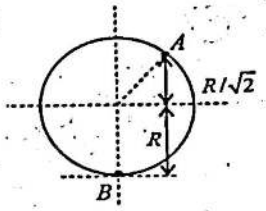
$mu = (M + m)V$

$10^{-2} \times 2 \times 10^2 \triangleq 1 \times V$

$V \triangleq 2\text{m/s}$

$h = \frac{V^2}{2g} = 0.2\text{m}$

88. (*b*)



Apply work energy theorem between A and B

$\Rightarrow mg \times \left(\frac{R}{\sqrt{2}} + R\right) = \frac{1}{2}mv_B^2 - 0$

$\Rightarrow mgR\frac{\left(\sqrt{2}+1\right)}{\sqrt{2}} = \frac{1}{2}mv_B^2$

$v_B = \sqrt{gR\frac{2\left(\sqrt{2}+1\right)}{\sqrt{2}}}$

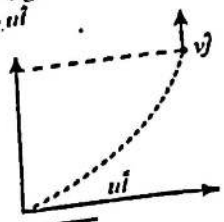
$v_s = \sqrt{\frac{10 \times 14 \times 2(-}{1.4}}$

89. (*b*)

90. (*b*) Let the speed of stone be *v* when string is horizontal from the conservation of energy.

$v = \sqrt{u^2 - 2gL}$

$\Delta v = v\hat{j} - u\hat{i}$



or, $\Delta v = \sqrt{u^2 + v^2}$

$\Delta v = \sqrt{u^2 + u^2 - 2gL}$

$\Delta v = \sqrt{2u^2 - 2gL} \Rightarrow \Delta v = \sqrt{2(u^2 - gL)}$

$x = 2$

91. [10] For the bob to complete the vertical circular motion,

$v_{bob} = \sqrt{5gl} = \sqrt{5 \times 10 \times 2} = 10\text{ m/s}$

From the law of conservation of momentum,

$75 \times v = 75 \times \frac{v}{3} + 50 \times 10 \Rightarrow v = 10\text{ m/s}$

92. [5] Let *v* is velocity at highest position.

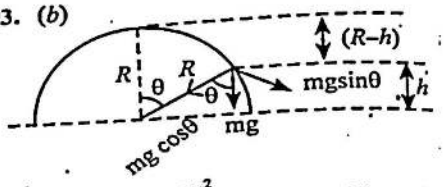
$T_{max} = 5T_{min}$

$\Rightarrow \frac{mg + \frac{m\left(v^2 + 4gl\right)}{l}}{5\frac{mv^2}{l} - mg} \Rightarrow 4.\frac{v^2}{l} = 10g$

$\Rightarrow \frac{T_{max}}{T_{min}} = 5$

$\Rightarrow v = \sqrt{\frac{5}{2}gl} = \sqrt{\frac{5}{2} \times 10 \times 1} = 5\text{ m/s}$

93. (*b*)



$mg\cos\theta = \frac{mv^2}{R}$ ...(1)

$\cos\theta = \frac{h}{R}$

Energy conservation

$mg\{R - h\} = \frac{1}{2}mv^2$ ...(2)

from (1) & (2) $\Rightarrow mg\left\{\frac{h}{R}\right\} = \frac{2mg\{R-h\}}{R}$

$h = \frac{2R}{3} = 2\text{m}$

@FAKE_CBSE_@RAJ EDUNET

JEE-Advanced

1. (d) $dW = \vec{F}.d\vec{s}$

$= \vec{F}.(dx\hat{i} + dy\hat{i})$

$= K\int \frac{xdx}{(x^2+y^2)^{3/2}} + \frac{ydy}{(x^2+y^2)^{3/2}}$

$W = K\int_a^0 xd + \int_0^a ydy$ $[\because x^2 + y^2 = a^2]$

$= \frac{K}{a^3}\left(\frac{-a^2}{2} + \frac{a^2}{2}\right) = 0$

As, F is along r or along the radial direction. So, work done is zero.

2. (c) Slope of graph $= \frac{4}{0-3} = \frac{-4}{3}$

Hence the value of force at $t = 4.5$ sec can

be calculated as, slope $= \frac{F_{at\,4.5\,sec}}{4.5-3}$

$\frac{-4}{3} = \frac{F_{at\,4.5\,sec}}{1.5} \Rightarrow F_{at\,4.5\,sec} = -2N$

Area under $F - t$ graph will gives us change in momentum $= \Delta P$

$\Delta P = \left(\frac{4\times 3}{2}\right) - \left(\frac{1.5\times 2}{2}\right) = 4.5$

$P_f - P_i = P_f - 0 = 4.5$

$\because$ Block is at rest at $t = 0$

$P_f = 4.5\ K$ gm/s

Kinetic Energy,

$\therefore KE = \frac{P_f^2}{2\,m} = \frac{(4.5)^2}{2\times 2} = 5.0625$ J

3. (c) Given, Force, $\vec{F} = -K(y\hat{i} + x\hat{j})$ Small displacement, $\vec{d} = dx\hat{i} + dy\hat{j}$

Small work done,

$dw = \vec{F}\cdot\vec{d} = -K(y\hat{i} + x\hat{j})\cdot(dx\hat{i} + dy\hat{j})$

$dw = -K(ydx + xdy) = -Kd(xy)$

On integrating dw we get,

$W = \int_{(a,0)}^{(a,a)} dw = -Kxy\Big|_{(a,0)}^{(a,a)} = -Ka^2$

$\therefore$ the work done $= -Ka^2$

4. (d) The weight of hanging part $\left(\frac{L}{3}\right)$ of chain is $\left(\frac{1}{3}Mg\right)$.

This weight acts at the center of gravity of the hanging part.

The distance of center of gravity from the table is $\left(\frac{L}{6}\right)$.

As work done = force × distance

$\therefore W = \frac{Mg}{3}\times\frac{L}{6} = \frac{mgL}{18}$.

5. [0.75] $\vec{F} = (\alpha y\hat{i} + 2\alpha x\hat{j})$

$W_{AB} = (-1\hat{i}).(1\hat{i}) = -1$J

$\left[\vec{F} = -1\hat{i} + 2\alpha x\hat{j}\right]$

$\left[\vec{S} = 1\hat{i}\right]$

Similarly, $W_{BC} = 1$J.

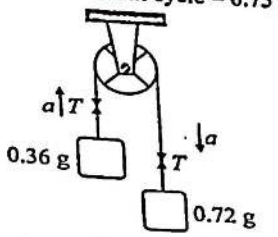
$W_{CD} = 0.25$ J

$W_{DE} = 0.5$ J

$W_{EF} = W_{FA} = 0.75$ J

$\therefore$ Net work in cycle $= 0.75$ J

6.



$a = \frac{\text{Total pulling force}}{\text{Total mass}}$

$= \frac{0.72\,g - 0.36\,g}{0.72 + 0.36} = \frac{g}{3}$

By eq. of motion

$s = \frac{1}{2}at^2 = \frac{1}{2}\left(\frac{g}{3}\right)(1)^2 = \frac{g}{6}$

$T - 0.36\,g = 0.36a = 0.36\frac{g}{3}$

$T = 0.36\,g + 0.36\frac{g}{3} = 0.48\,g$

work done on 0.36 kg block

$= T.S = TS\cos 0° = (0.48\,g)\left(\frac{g}{6}\right)(1)$

$= 0.08\,(g^2) = 0.08(10)^2 = 8$J

7. Given, $t = \sqrt{x} + 3$

$x = (t-3)^2 = t^2 - 6t + 9$

$x = t^2 - 6t + 9$ ...(i)

Differentiating this equation w.r.t time, we get velocity.

$v = \frac{dx}{dt} = 2t - 6$ ...(ii)

(a) $v = 0 \Rightarrow 2t - 6 = 0 \Rightarrow t = 3$s

Substituting in eqn. (i), we get

$x = 3^2 - 6\times 3 + 9 = 0$

i.e. displacement of particle is zero when velocity is zero.

(b) From eqn. (ii), velocity of particle at $t = 0$ is

$v_i = 2t - 6 = 2(0) - 6 = -6$ m/s

$v_i = -6$ m/s

and at $t = 6$s

$v_f = 2t - 6 = 2(6) - 6 = 6$ m/s

$v_f = 6$ m/s

From work energy theorem,

(Work done)$_{\text{by all forces}}$ = change in kinetic energy

$\frac{1}{2}m\left[v_f^2 - v_i^2\right] = \frac{1}{2}m\left[(6)^2 - (-6)^2\right] = 0$

8. (a) We know that, $F = -\frac{dU}{dx}$

$dU = -Fdx$

On integrating, we get

$\int_0^{u(x)} dU = -\int_0^x Fdx$

$U(x) - 0 = -\int_0^x kxdx$

$U(x) = -\frac{kx^2}{2}$

(we can compare this with the equation of the downward facing parabola.)

9. (d) Given, Force $F(x) = -kx + ax^3$

We know that, $F = -\frac{dU}{dx}$

$dU = -Fdx$

$\int_0^{u(x)} dU = -\int_0^x Fdx$

$U(x) - U(0) = -\int_0^x F(x)\,dx$

Let us assume $U(0) = 0$.

$U(x) - 0 = -\int_0^x \left(-kx + ax^3\right)dx$.

$U(x) = \frac{kx^2}{2} - \frac{ax^4}{4}$ ...(i)

$U(0) = 0$ this satisfying our assumption, put $x = 0$ in equation (i) you are able to see that

Now check that at for what values of x, $U(x) = 0$ is satisfying

From equation (i)

$U(x) = \frac{kx^2}{2} - \frac{ax^4}{4} = 0$

$x^2(2k - ax^2) = 0$

$x = 0, x = \pm\sqrt{\frac{2k}{a}}$

And for $x \geq 0$ in graph the curve will cut x-axis twice

$\frac{d(U(x))}{dx} = kx - ax^3 = x(k - ax^2)$

@FAKE_CBSE_Y@RAJ_EDUNET

Now for $\frac{d(U(x))}{dx}=0$ we will get

$x=0,\sqrt{\frac{k}{a}}$

It means at $x=0$ and at $x=\sqrt{\frac{k}{a}}$ the slope of curve is zero. So, the only graph possible is option *d*.

10. (c) (A) $F_x=\frac{-dU}{dx}=-\frac{U_0}{2}\times\left[1-\left(\frac{x}{a}\right)^2\right]\times\left(\frac{-2x}{a}\right)\times\left(\frac{1}{a}\right)$

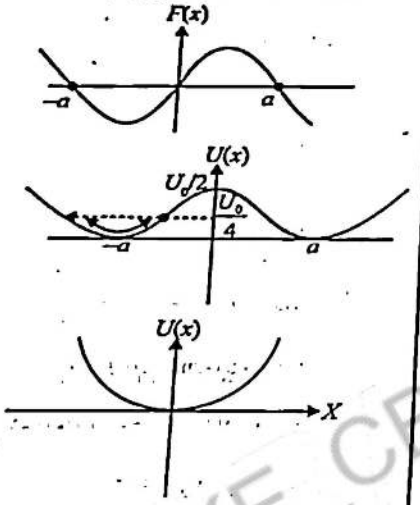
$=\frac{2xU_0}{dx}(a+x)(a-x)$

$=-\frac{2U_0}{a^4}(x-a)(x)(x+a)$

$F=0$ at $x=0, x=a, x=-a$

and $U=0$ at $x=-a, x=a$

Hence, P, Q, R can connect to A



For attractive force $F\ a-x$ near the origin

So S cannot connect to A

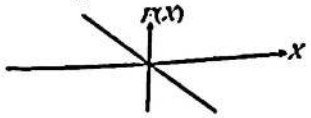
Calculating $\frac{d^2U}{dx^2}$ at $x=-a$

$\frac{d^2U}{dx^2}=\frac{2U_0}{a^4}.=((x+a)(x-a)+x(x-a)+x(x+a))$

At $x=-a$ double derivative is positive, this implies that there is minima of curve at that point and it will oscillate about the point as it is minimum P.E. (v) and total energy $U_0/4$ of particle is less than maximum P.E. $U_0/4$ applies Correct answers are P, Q, R, T.

(B) $U_2(x)=\frac{U_0}{2}\left(\frac{x}{a}\right)^2$

$F_x=\frac{-dU}{dx}=-\frac{U_0}{2}\times\left(\frac{1}{a^2}\right)\times 2x=-\frac{U_0x}{a^2}$



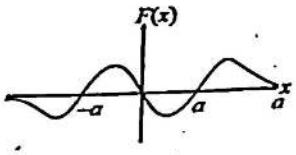
$F_x=0$ at $x=0$

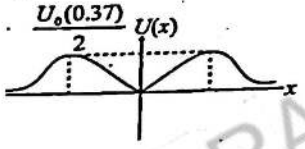
Hence, Q, S are the answers of B.

(C) $U_3(x)=\frac{U_0}{2}\left(\frac{x}{a}\right)^4\exp\left[-\left(\frac{x}{a}\right)^4\right]$

$F_x=\frac{-dU}{dx}$

$F_x=-\frac{ux.(x^2-a^2)e^{\frac{-x^2}{a^2}}}{a^4}$

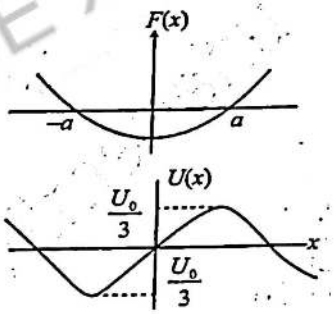




$Fx=0$ at $x=0, a, -a$

Hence, P, Q, R, S are the answers of C

(D) $F_x=-\frac{dU}{dx}=-\frac{U_0}{2a^3}[(x-a)(x+a)]$



P, R and T are the answers of D

11. (c) Energy in spring S_1 when it compressed

$=\frac{1}{2}kx^2$

Energy in spring S_2 when it compressed

$=\frac{1}{2}kx^2$

Using conservation of energy,

$\frac{1}{2}kx^2=\frac{1}{2}(4k)y^2\ \therefore\frac{y}{x}=\frac{1}{2}$

12. (c) In statement I loss in mechanical energy $\Delta U_1=\frac{1}{2}mv^2$. Also, loss in mechanical energy in case (II) is ΔU_2

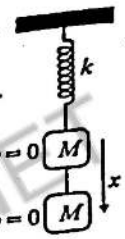
$=\frac{1}{2}mv^2-mgh\Rightarrow\Delta U_2<\Delta U_1$

So, statement I is correct.

In statement II Coefficient of friction will not change or this statement is wrong.

13. (b) Assume x to be the maximum extension in the spring.

By applying conservation of mechanical energy, Change in gravitational potential energy = Change in spring potential energy



$\therefore\ Mgx=\frac{1}{2}kx^2$

$x=\frac{2Mg}{k}$

14. (c) Kinetic energy

$K=\frac{1}{2}mv^2=\frac{1m^2v^2}{2}.\frac{1}{m}=\frac{p^2}{2m}$; Where p is momentum

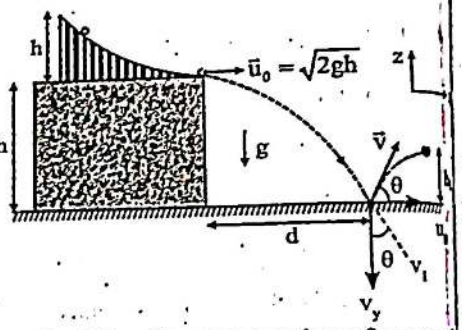
Given that, $K_1=K_2$

$\frac{p_1^2}{2m_1}=\frac{p_2^2}{2m_2}$

$\frac{p_1^2}{p_2^2}=\frac{m_1}{m_2}=\frac{1}{4}$

$\frac{p_1}{p_2}=\frac{1}{2}$

15. (a, c, d)



Applying the conservation of energy height

@FAKE_CBSE_KOTA_RAJ_EDUNET

$0 + mgh = \frac{1}{2}mu_0^2 + 0$

$v_0 = \sqrt{2gh}$

$\vec{u}_0 = \sqrt{2gh}\,\hat{x}$

Again, applying conservation of energy for height $3h$.

$mg(3h) = \frac{1}{2}mv_y^2$ (Along $-\hat{y}$)

$\therefore v_y = \sqrt{2g(3h)}$

$\therefore \vec{v}_1 = u_0\hat{x} - v_y\hat{z} = \sqrt{2gh}\,\hat{x} - \sqrt{2g3h}\,\hat{z}$

$\vec{v} = u_0\hat{x} + cv_y\hat{z}$

$\vec{v} = \sqrt{2gh}\,\hat{x} + \sqrt{2g3h} \times \frac{1}{\sqrt{3}}\hat{z}$

$= \sqrt{2gh}\,\hat{x} + \sqrt{2gh}\,\hat{z}$

$\tan\theta = \frac{\sqrt{2g3h}}{\sqrt{2gh}} = \sqrt{3}, \theta = 60°$

$h_1 = \frac{v_{1y}^2}{2g} = \frac{2gh}{2g} = h$

$d = v_x t = \sqrt{2gh_1} \times \sqrt{\frac{2 \times 3h_1}{g}}$

$= \sqrt{2gh_1}\sqrt{\frac{6h_1}{g}} = 2\sqrt{3h_1} \Rightarrow \frac{d}{h_1} = 2\sqrt{3}$

16. (a,d) By the energy conservation (ME) between bottom point and point 'y'

$\frac{1}{2}mv_0^2 = mgh + \frac{1}{2}mv_1^2$

$\therefore v_1^2 = v_0^2 - 2gh$ ...(i)

Now at point 'y' the centripetal force provided by the component of mg

$\therefore mg\sin 30° = \frac{mv_1^2}{R}$

$\therefore v_1^2 = \frac{gR}{2}$

$\therefore$ from (i)

$\frac{gR}{2} = v_0^2 - 2gh$

At point x and z of circular path, the points are at same height but less then h. So the velocity more than a point y.

So required centripetal $= \frac{mv^2}{r}$ is more.

17. (a, b, d) kinetic energy

$K = \frac{1}{2}mv^2$

$\frac{dK}{dt} = mv\frac{dv}{dt}$

Given, $\frac{dK}{dt} = \gamma t$

$mv\frac{dv}{dt} = \gamma t$

$\int_0^v v\,dv = \int_0^t \frac{\gamma}{m}t\,dt$

$\frac{v^2}{2} = \frac{\gamma t^2}{m2}$

$v = \sqrt{\frac{\gamma}{m}}t \Rightarrow$ The speed of the particle is proportional to time

$a = \frac{dv}{dt} = \sqrt{\frac{\gamma}{m}}$

$\therefore F = ma$

$= \sqrt{\gamma m} =$ constant $\Rightarrow$ The force applied on the particle is constant

$\therefore V = \frac{ds}{dt} = \sqrt{\frac{\gamma}{m}}t \Rightarrow s = \sqrt{\frac{\gamma}{m}}\frac{t^2}{2}$

The distance of the particle from the origin is proportional to t^2.

And force is constant and displacement between any two points on the x-axis is always constant. So work done by force not depending on the path . Hence force is conservative here.

18. (c, d) The force is acting perpendicular to the direction of velocity so it is changing the the velocity but not speed .

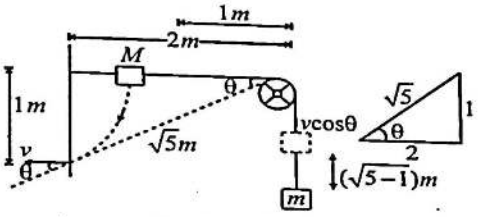
Hence kinetic energy is not changing .

Kinetic Energy $= \frac{1}{2}mv^2$

By another technique , we can also see that force is acting perpendicular to velocity it signifies that work done in that direction is zero.

Then by work energy theorem we can say that $\Delta K = 0$ and, direction of force is changing with the direction of velocity hence, acceleration is not constant and this is happening like circular motion because when the constant force is acting perpendicular to the direction of velocity of particle then that moves in circular motion as that force working as centripetal force .

19.



Assume M strikes with speed v.

$\Rightarrow$ Then from the FBD it can be said that velocity of m at this instant will be $v\cos\theta$ or $\frac{2}{\sqrt{5}}v$.

$\Rightarrow$ After this M will fall a distance of 1 m while m will rise up by $(\sqrt{5}-1)$ m.

$\Rightarrow$ By energy conservation, (PE = Potential energy; KE = Kinetic energy)

$KE_i + PE_i = KE_f + PE_f$; take the position of M as reference

$0 + 0 = \frac{1}{2}Mv^2 + \frac{1}{2}m\left(\frac{2v}{\sqrt{5}}\right)^2 + mg(\sqrt{5}-1) + mg(-1)$

$0 = \frac{1}{2}\times 2\times v^2 + \frac{1}{2}\times 0.5\times\left(\frac{2v}{\sqrt{5}}\right)^2 + (0.5)(9.8)(\sqrt{5}-1) + (2)(9.8)(-1)$

$18.6 = v^2 + \frac{v^2}{5} + 4.9\sqrt{5} - 4.9$

$\frac{6v^2}{5} = 23.5 - 4.9\sqrt{5}$ w

$\frac{6v^2}{5} = 23.5 - 10.96 = 12.54$

$v = \sqrt{\frac{5}{6}\times 12.54}$

$v = 3.23$ m/s

20. Normal reaction between blocks A and C will be zero. Therefore, there will be no friction between them. Both A and B are moving with uniform speed. Therefore, force on them should be zero.

$\mu m_B g$

$m_A g$

For equilibrium of A

$m_A g = kx$

$\therefore x = \frac{m_A g}{k} = \frac{(2)(9.8)}{1960} = 0.01$ m

For equilibrium of B

$\mu m_B g = T = kx = m_A g$

$m_B = \frac{m_A}{\mu} = \frac{2}{0.2} = 10$ kg

Energy stored in spring

$U = \frac{1}{2}kx^2 = \frac{1}{2}(1960)(0.01)^2 = (0.098\text{ J})$

21. $\frac{1}{2}Mv_c^2 = Mgy - \mu Mg\cos\theta\ AC\ \theta = \angle ACB$

$\frac{1}{2}Mv_c^2 = Mgy - \mu Mg\frac{x}{AC}AC$

$\frac{1}{2}Mv_c^2 = Mgy - \mu Mgx$

$v_c = \sqrt{2gy - 2\mu gx}$

Let angle DFE be β

And angle DGH be α

@FAKE_CBSE_NCERT_EDUNET

$\frac{1}{2}Mv_c^2 = Mgy - \mu Mg\cos\alpha \cdot DG - \mu Mg\cos\beta \cdot GF$

$\frac{1}{2}Mv_c^2 = Mgy - \mu Mg\frac{HG}{DG}\cdot DG - \mu Mg\frac{IF}{GF}\cdot GF$

$\frac{1}{2}Mv_c^2 = Mgy - \mu Mg(HG + IF);\ HG = EI$

$\frac{1}{2}Mv_c^2 = Mgy - \mu Mg(EI + IF)$

$\frac{1}{2}Mv_c^2 = Mgy - \mu Mgx;\ EI + IF = x$

$v_c = \sqrt{2gy - 2\mu gx}$

$v_c = v_r = \sqrt{2gy - 2\mu gx}$

22. (*b*) Height fallen up to point Q

$h = R\sin 30^\circ = 40 \times \frac{1}{2} = 20$ m

Work done against friction = Initial mechanical energy − Final mechanical energy $= mgh - \frac{1}{2}mv^2$ Putting the values, we get

$150 = 1 \times 10 \times 20 - \frac{1}{2} \times 1 \times v^2 \Rightarrow v = 10$ m/s

23. (*a*) At point Q, component of weight along PQ (radially outwards) is mg cos 60° or $\frac{mg}{2}$.

Normal reaction is radially inwards

or $N = \frac{mg}{2} + \frac{mv^2}{R}$

$= \frac{1 \times 10}{2} + \frac{1 \times (10)^2}{40} = 7.5$ N

24. [5] In ΔPOQ, $PQ^2 = PO^2 + OQ^2 = 3^2 + 4^2 = 25$

$PQ = 5$ m

By work-energy theorem

Work done by all forces exerted on body = Change in kinetic energy of that body Or

$W_F + W_{mg} = K_f - K_i$

$|F|\,|s|\cos\theta + mg(-h) = K_f - 0$

$18 \times 5 + (1 \times 10)(-4) = K_f$

$90 - 40 = K_f$

$K_f = 50\text{ J} = 5 \times 10\text{ J} = n \times 10\text{ J}$

$\therefore n = 5$

25. [4] By applying work energy theorem

Potential energy in spring + Work done against friction = Initial kinetic energy

$\frac{1}{2}kx^2 + \mu mgx = \frac{1}{2}mv^2$

$\frac{1}{2} \times 2 \times (0.06)^2 + 0.1 \times 0.18 \times 10 \times 0.06 = \frac{1}{2} \times 0.18 \times v^2$

$0.0036 + 0.0108 = 0.9\,v^2$

$\frac{0.0144}{0.9} = v^2$

$0.16 = v^2$

$v = 0.4 = \frac{4}{10} = \frac{N}{10}$

$\therefore N = 4$

26. [150] Mass of the ball, $m = 0.15$ kg

Maximum height, $h = 20$ m

Force applied by machine is F

Horizontal distance moved $x = 0.2$ m

acceleration due to gravity, $g = 10\ ms^{-2}$

The velocity at maximum height is 0 m/s

Using $v^2 - u^2 = 2as$, we get

$v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20}$

$v = 20$ m/s

The work done by machine is converted to kinetic energy of the ball, equating the two,

$Fx = \frac{1}{2}mv^2$

$F \times 0.2 = \frac{1}{2} \times 0.15 \times (20)^2$

$F = 150$ N

Hence, the force applied by the machine is $F = 150$ N.

27. (*c*) We know that,

$F = \frac{dP}{dt} = \frac{d(mv)}{dt} = m\frac{dv}{dt} + v\frac{dm}{dt}$

Here velocity of wind is constant. So,

$F = v\left(\frac{dm}{dt}\right)$

Let us consider the density of air is ρ and v volume of air is striking in dt time to the blades of generator of cross section area A

$F = v\left(\frac{d(\rho Avdt)}{dt}\right)$

$= v(\rho Av)\left(\frac{d(dt)}{dt}\right) = \rho Av^2$

Power $= F.v = \rho Av^2 . v = \rho Av^3$

Power output $\propto \rho Av^3$

Power output $\propto v^3$

28. (*b*) Given Centripetal acceleration

$a_c = k^2rt^2$

$\frac{v^2}{r} = k^2rt^2$

$v^2 = k^2r^2t^2$

$v = krt$

Tangential acceleration,

$a_t = \frac{dv}{dt} = kr$

Then, tangential force

$= F_t = ma_t = mkr$

Work is always done due to tangential force.

Work done by the centripetal force is zero. Because the centripetal force is perpendicular to the displacement. And displacement is along the tangential direction.

Hence, power delivered is Ftv

$= mkr \times krt = mk^2r^2t$

29. (*c*) Let's consider power P.

The distance moved by the body (of mass m) is s.

$P = f.v$ .....(*i*); $v = \frac{s}{t}$ $f = ma$ .... (*ii*)

$a = \frac{s}{t^2}$ from equation (*i*) and (*ii*), we get

$P = \frac{ms}{t^2} \times \frac{s}{t}, s^2 = \frac{Pt^3}{m}$ from the above equation, we get

$S^2 \propto t^3 \Rightarrow S \propto t^{3/2}$

30. [5] Work done $= F \times s = ma \times s$

$W = \frac{m}{2}2as = \frac{mv^2}{2}$;

$\because v^2 = u^2 + 2as$ and $u = 0$

Power, $P = \frac{dw}{dt}$

$W = \int Pdt = \int_0^5 0.5dt$

$\frac{mv^2}{2} = 0.5[t]$

$v = \sqrt{\frac{0.5 \times 5 \times 2}{0.2}} = 5$ m.

31. (*d*) $h = I - I\cos\theta$ Here PE = potential energy, KE = kinetic energy

It is given that, velocity v at position A is just sufficient to make it reach the point B

So we can say that $v = \sqrt{5Lg}$

Using the concept of conservation of mechanical energy

$PE_A + KE_A = PE_B + KE_A$

$0 + \frac{1}{2}mv^2 = mg(I - I\cos\theta) + \frac{1}{2}m$ ...(*i*)

It is also said that we want that θ at which speed B is half of that speed at $V = v/2$ put in equation (*i*)

@RAJ_EDUNET @EARN_CBSE

$$0+\frac{1}{2}mv^2=mg(L-L\cos\theta)+\frac{1}{2}m\left(\frac{v}{2}\right)^2$$

$$\frac{1}{2}mv^2-\frac{1}{8}mv^2=mg(L-L\cos\theta)$$

$$\frac{3}{8}v^2=g(L-L\cos\theta) \quad ...(ii)$$

Put $v=\sqrt{5Lg}$ in equation (*ii*)

$$\frac{3}{8}\left(\sqrt{5Lg}\right)^2=g(L-L\cos\theta)$$

$$\frac{15}{8}Lg=g(L-L\cos\theta)$$

$$\frac{15}{8}=1-\cos\theta$$

$$\cos\theta=1-\frac{15}{8}=\frac{-7}{8}$$

$$\theta=\cos^{-1}\left(\frac{-7}{8}\right)=151.05\approx\frac{5\pi}{6}$$

Which belongs to the range of

$$\frac{3\pi}{4}<\theta<\pi$$

32. *(d)* By assuming the lowest point as the reference

Let us take velocity at horizontal point be V.

Energy at Lowest point $= PE + KE$

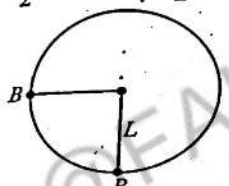
$$=0+\frac{1}{2}mu^2$$

Energy at horizontal point $= PE + KE$

$$=mgL+\frac{1}{2}mV^2$$

By using conservation of mechanical energy,

$$\frac{1}{2}mu^2=mgL+\frac{1}{2}mv^2$$



$$V_2=u^2-2gl$$

$$V=\sqrt{u^2-2gL}$$

in vector from we have

$$V=\sqrt{u^2-2gL}\,\hat{j}$$

And velocity at lowest point is $u\hat{i}$.

$$\text{Difference}=V-u=\sqrt{u^2-2gL}\,\hat{j}-u\hat{i}$$

$$|V-u|=\sqrt{u^2-2gL+u^2}=\sqrt{2u^2-2gL}$$

$$|\Delta V|=\sqrt{2(u^2-gL)}$$

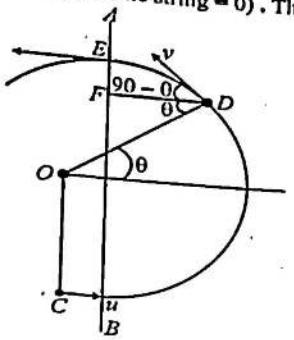
33. Let us assume that string will slag when particle reach at D.

By seeing the given conditions we see that from B to D it will do circular motion and after that it will follow a parabolic path.

Now by applying the conservation of mechanical energy at point B and D

$$\frac{1}{2}mu^2=\frac{1}{2}mv^2+mgL(1+\sin\theta)$$

And at point D there is slagging (it means Tension in the string = 0). Then,



$$mg\sin\theta=\frac{mv^2}{L}\Rightarrow g\sin\theta=\frac{v^2}{L}$$

$$\sin\theta=\frac{v^2}{gL} \quad ...(i)$$

Because after point D it is following parabolic path we can say that

$$FD=L\cos\theta-\frac{L}{\theta}=\frac{1}{2}(\text{Max range})$$

$$=\frac{1}{2}\times\frac{p^2\sin2(90-\theta)}{g}$$

$$L\left(\cos\theta-\frac{1}{8}\right)=\frac{1}{2}\times\frac{v^2\sin2(90-\theta)}{g} \quad ...(ii)$$

From (*i*) and (*ii*)

$$\left(\cos\theta-\frac{1}{8}\right)=\sin\theta\times\frac{\sin2(90-\theta)}{2}$$

$$\left(\cos\theta-\frac{1}{8}\right)$$

$$=\sin\theta\times\frac{2\sin(90-\theta)\cos(90-\theta)}{2}$$

$$\left(\cos\theta-\frac{1}{8}\right)=\sin\theta\times\frac{2\sin\theta\sin\theta}{2}$$

$$\left(\cos\theta-\frac{1}{8}\right)=\sin^2\theta\cos\theta$$

$$=(1-\cos^2\theta)\cos\theta$$

$$\cos\theta-\frac{1}{8}=\cos\theta-\cos^3\theta$$

$$\cos\theta=1/2\ \theta=\pi/3$$

From equation (*i*)

$$v=\sqrt{gL\sin\theta}=\sqrt{gL\sin60}=\sqrt{\frac{\sqrt{3}}{2}gL}$$

By substituting the value of v into the equation of conservation of energy

$$\frac{1}{2}mu^2=\frac{1}{2}m\left(\sqrt{\frac{\sqrt{3}}{2}gL}\right)^2+mgL(1+\sin\theta)$$

$$\frac{1}{2}mu^2=\frac{1}{2}m\frac{\sqrt{3}}{2}gL+mgL(1+\sin60)$$

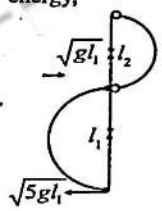
$$u^2=\frac{\sqrt{3}}{2}gL+2gL\left(1+\frac{\sqrt{3}}{2}\right)$$

$$u^2=gL\left(\frac{3\sqrt{3}}{2}+2\right)$$

$$u=\sqrt{\left(\frac{3\sqrt{3}+4}{2}gL\right)}$$

34. [5] As we know, Minimum velocity given to bob to complete full circle $(u)=\sqrt{5gl_1}$

By using conservation mechanical energy,



$$\frac{1}{2}mu^2=mg(2l_1)+\frac{1}{2}mv^2$$

$$\frac{1}{2}m\left(\sqrt{5gl_1}\right)^2=2mgl_1+\frac{1}{2}mv^2$$

$$v=\sqrt{gl_1}$$

Velocity of A at highest position $v=\sqrt{gl_1}$.

At the highest position of bob A, it is colliding elastically with bob B of same mass m.

Then we can say that the velocity will be interchanged between these bob.

So the velocity of bob B at its lower point is $\sqrt{gl_1}$

And for the completing the full circle, minimum velocity required for bob B $=\sqrt{5gl_2}$

So, given condition is that bob B is completing the circle then,

$$\sqrt{gl_1}=\sqrt{5gl_2}\Rightarrow\frac{l_1}{l_2}=5$$

@FAKE_CBSE_KORAL_ENGINEER

System of Particles and Centre of Mass

Scan for Sol

JEE-Main

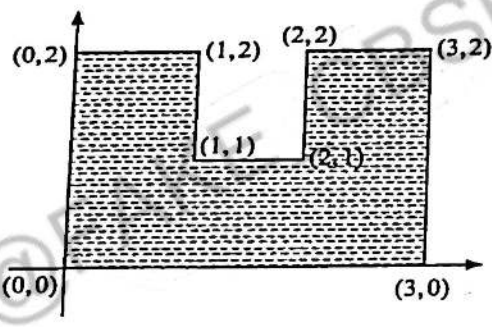
Position of COM

1. The identical spheres each of mass 2M are placed at the corners of a right angled triangle with mutually perpendicular sides equal to 4 m each. Taking point of intersection of these two sides as origin, the magnitude of position vector of the centre of mass of the system is $\frac{4\sqrt{2}}{x}$, where the value of x is _____

[1 Feb, 2024 (Shift-I)]

2. A uniform thin metal plate of mass 10 kg with dimensions is shown. The ratio of x and y coordinates of center of mass of plate in $n/9$. The value of n is_____.

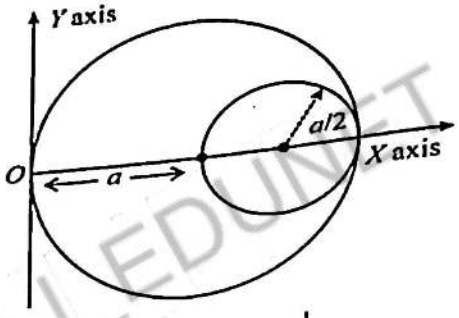
[08 April, 2024 (Shift-I)]



3. The distance of centre of mass from end A of a one dimensional rod (AB) having mass density $Q = Q_0\left(1-\frac{x^2}{L^2}\right)$ kg/m and length L (in meter) is $\frac{3L}{\alpha}m$. The value of α is _____. (where x is the distance from end A)

[28 July, 2022 (Shift-II)]

4. A circular hole of radius $\left(\frac{a}{2}\right)$ is cut of a circular disc of radius 'a' as shown in figure. The centroid of the remaining circular portion with respect to point 'O' will be: [24 Feb, 2021 (Shift-II)]



(a) $\frac{5}{6}a$ (b) $\frac{1}{6}a$

(c) $\frac{10}{11}a$ (d) $\frac{2}{3}a$

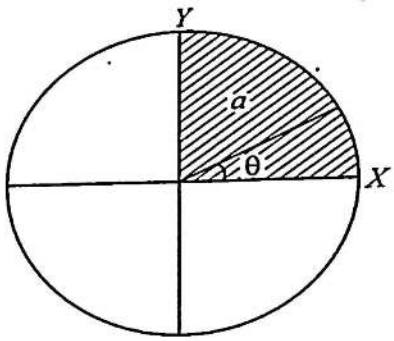
5. The position of the centre of mass of a uniform semi – circular wire of radius 'R' placed in $x-y$ plane with its centre at the origin and the line joining its ends as x-axis is given by $\left(0, \frac{xR}{\pi}\right)$. Then, the value of x is _____.

[22 July, 2021 (Shift-II)]

6. The disc of mass M with uniform surface mass density σ is shown in the figure. The centre of mass of the quarter disc (the shaded area) is at the position $\frac{x}{3}\frac{a}{\pi}, \frac{x}{3}\frac{a}{\pi}$ where x is __(Round off to the Nearest Integer)

[17 March, 2021 (Shift-II)]

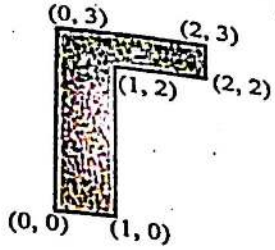
[a is an area as shown in the figure]



@RAJ_EDUNEET

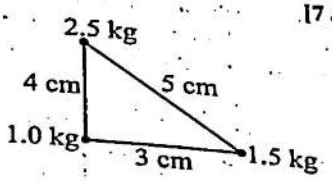
in figure) are:

...m flag shaped lamina ...e coordinates of the same are shown
[8 Jan, 2020 (Shift-I)]



(a) 8.....25 m, 1.50 m)
(b) (0.75 m, 0.75 m)
(c) (0.75 m, 1.75 m)
(d) (1 m, 1.75 m)

8. Three point particles of masses 10 kg, 1.5 kg and 2.5 kg are placed at three corners of a right angle triangle of sides 4.0 cm, 3.0 cm and 5.0 cm as shown in the figure. The center of mass of the system is at a point:
[7 Jan, 2020 (Shift-I)]



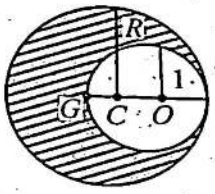
(a) 9.....6 cm right and 2.0 cm above 1kg mass
(b) 10.....0 cm right and 0.9 cm above 1 kg mass
(c) 11.....9 cm right and 2.0 cm above 1kg mass
(d) 12.....5 cm right and 1.2 cm above 1kg mass

9. A rod of length L has non-uniform linear mass density given by $\rho(x) = a + b\left(\frac{x}{L}\right)^2$ where a and b are constants and $0 \le x \le L$. The value of x for the centre of mass of the rod is at: [9 Jan, 2020 (Shift-II)]

(a) $\frac{4}{3}\left(\frac{a+b}{2a+3b}\right)L$ (b) $\frac{3}{4}\left(\frac{2a+b}{3a+b}\right)L$

(c) $\frac{3}{2}\left(\frac{2a+b}{3a+b}\right)L$ (d) $\frac{3}{2}\left(\frac{a+b}{2a+b}\right)L$

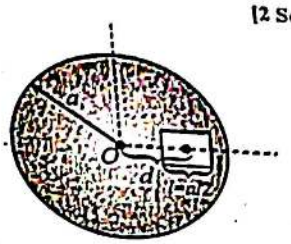
10. As shown in figure. When a spherical cavity (centred at O) of radius 1 is cut out of a uniform sphere of radius R (centred at C), the centre of mass of remaining (shaded) part of sphere is at G, i.e on the surface of the cavity. R can be determined by the equation:
[8 Jan, 2020 (Shift-II)]



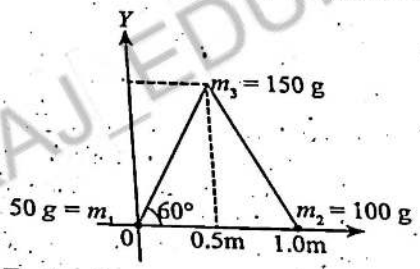
(a) $(R^2 + R + 1)(2 - R) = 1$
(b) $(R^2 + R - 1)(2 - R) = 1$
(c) $(R^2 - ssR + 1)(2 - R) = 1$
(d) $(R^2 - R - 1)(2 - R) = 1$

11. The centre of mass of a solid hemisphere of radius 8 cm is x cm from the centre of the flat surface. Then value of x is _____.
[6 Sep, 2020 (Shift-II)]

12. A square shaped hole of side $l = \frac{a}{2}$ is carved out at a distance $d = \frac{a}{2}$ from the centre 'O' of a uniform circular disk of radius a. If the distance of the centre of mass of the remaining portion from O is $-\frac{a}{x}$, value of x (to the nearest integer) is _____.
[2 Sep, 2020 (Shift-II)]



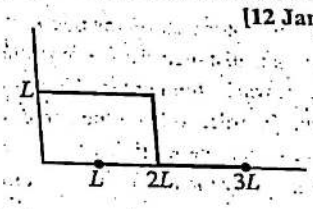
13. Three particles of masses 50 g, 100g and 150g are placed at the vertices of an equilateral triangle of side 1 m (as shown in the figure). The (x, y) coordinates of the centre of mass will be:
[12 April, 2019 (Shift-II)]



(a) $\left(\frac{\sqrt{3}}{7}m, \frac{7}{12}m\right)$ (b) $\left(\frac{7}{12}m, \frac{\sqrt{3}}{8}m\right)$

(c) $\left(\frac{\sqrt{3}}{4}m, \frac{5}{12}m\right)$ (d) $\left(\frac{7}{12}m, \frac{\sqrt{3}}{4}m\right)$

14. The position vector of the centre of mass $\vec{r}$ cm of an asymmetric uniform bar of negligible area of cross-section as shown in figure is:
[12 Jan, 2019 (Shift-I)]



(a) $\vec{r}\,(\text{cm}) = \frac{13}{8}L\hat{x} + \frac{5}{8}L\hat{y}$

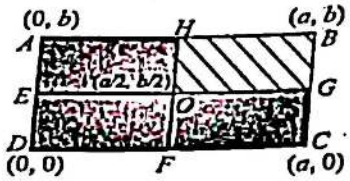
(b) $\vec{r}\,(\text{cm}) = \frac{5}{8}L\hat{x} + \frac{13}{8}L\hat{y}$

(c) $\vec{r}\,(\text{cm}) = \frac{3}{8}L\hat{x} + \frac{11}{8}L\hat{y}$

(d) $\vec{r}\,(\text{cm}) = \frac{11}{8}L\hat{x} + \frac{3}{8}L\hat{y}$

@NKE_JOSEY @RAJ_EDUCATE

15. A uniform rectangular thin sheet ABCD of mass M has length a and breadth b, as shown in the figure. If the shaded portion HBGO is cut off, the coordinates of the centre of mass of the remaining portion will be: [8 April, 2019 (Shift-II)]



(a) $\left(\frac{2a}{3}, \frac{2b}{3}\right)$ (b) $\left(\frac{5a}{3}, \frac{5b}{3}\right)$

(c) $\left(\frac{3a}{4}, \frac{3b}{4}\right)$ (d) $\left(\frac{5a}{12}, \frac{5b}{12}\right)$

16. Two bodies of mass 1 kg and 3 kg have position vectors $\hat{i}+2\hat{j}+\hat{k}$ and $-3\hat{i}-2\hat{j}+\hat{k}$ respectively. The magnitude of position vector of centre of mass of this system will be similar to the magnitude of vector: [29 July, 2022 (Shift-I)]

(a) $\hat{i}-2\hat{j}+\hat{k}$ (b) $-3\hat{i}-2\hat{j}+\hat{k}$

(c) $-2\hat{i}+2\hat{k}$ (d) $-2\hat{i}-\hat{j}+\hat{k}$

17. Three identical spheres each of mass M are placed at the corners of a right angled triangle with mutually perpendicular sides equal to 3 m each. Taking point of intersection of mutually perpendicular sides as origin, the magnitude of position vector of centre of mass of the system will be $\sqrt{x}$ m. The value of x is _____. [25 July, 2022 (Shift-II)]

Motion of COM

18. In a system two particles of masses m_1 = 3kg and m_2 = 2kg are placed at certain distance from each other. The particle of mass m_1 is moved towards the center of mass of the system through a distance 2 cm. In order to keep the center of mass of the system at the original position, the particle of mass m_2 should move towards the center of mass by the distance _____ cm. [04 April, 2024

19. A piece of wood of mass 0.03 kg is dropped from the top of a 100 m height building. At the same time, a bullet of mass 0.02 kg is fired vertically upward, with a velocity 100 ms^{-1}, from the ground. The bullet gets embedded in the wood. Then the maximum height to which the combined system reaches above the top of the building before falling below is: ($g = 10\ ms^{-2}$) [10 Jan, 2019 (Shift-I)]

(a) 20 m (b) 30 m

(c) 40 m (d) 10 m

20. Two blocks of masses 10 kg and 30 kg are placed on the same straight line with coordinates (0, 0) and (x, 0) respectively. The block of 10 kg is moved on the same line through a distance of cm towards the other block. The distance through which the block of 30 kg must be moved to keep the position of centre of mass of the system unchanged is [27 June, 2022 (Shift-I)]

(a) 4 cm towards the 10 kg block

(b) 2 cm away from the 10 kg block

(c) 2 cm towards the 10 kg block

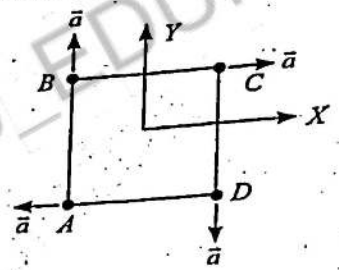
(d) 4 cm away from the 10 kg block

21. Two bodies of mass 1 kg and 3 kg have position vectors $\hat{i}+2\hat{j}+\hat{k}$ and $-3\hat{i}-2\hat{j}+\hat{k}$ respectively. The magnitude of position vector of centre of mass of this system will be similar to the magnitude of vector: [29 July, 2022 (Shift-I)]

(a) $\hat{i}-2\hat{j}+\hat{k}$ (b) $-3\hat{i}-2\hat{j}+\hat{k}$

(c) $-2\hat{i}+2\hat{k}$ (d) $-2\hat{i}-\hat{j}+\hat{k}$

22. Four particles A, B, C and D with masses $m_A = m$, $m_B = 2m$, $m_C = 3m$ and $m_D = 4m$ are at the corners of a square. They have accelerations of equal magnitude with directions as shown. The acceleration of the centre of mass of the particles is: [8 April, 2019 (Shift-I)]



(a) $\frac{a}{5}(\hat{i}-\hat{j})$ (b) Zero

(c) $\frac{a}{5}(\hat{i}\times\hat{j})$ (d) $a(\hat{i}+\hat{j})$

23. A man (mass = 50 kg) and his son (mass = 20 kg) are standing on a frictionless surface facing each other. The man pushes his son so that he starts moving at a speed of 0.70 ms^{-1} with respect to the man. The speed of the man with respect to the surface is: [12 April, 2019 (Shift-I)]

(a) 24.....20 ms^{-1} (b) 0.14 ms^{-1}

(c) 25.....47 ms^{-1} (d) 0.28 ms^{-1}

Impulse, Conservation of Momentum

24. A body of mass 1000 kg is moving horizontally with a velocity 6 m/s. If 200 kg extra mass is added, the final velocity (in m/s) is: [27 Jan, 2024 (Shift-I)]

(a) 6 (b) 2 (c) 3 (d) 5

@FAKE_CBSE_X @RAJ_EDUN

25. A stationary particle breaks into two parts of masses m_A and m_B which move with velocities v_A and v_B respectively. The ratio of their kinetic energies $(K_B : K_A)$ is:
[08 April, 2024 (Shift-I)]

(a) $v_B : v_A$ (b) $m_B : m_A$
(c) $m_B v_B : m_A v_A$ (d) 1 : 1

26. A particle of mass m moving with velocity v collides with a stationary particle of mass $2m$. After collision, they stick together and continue to move together with velocity
[10 April, 2023 Shift-I)]

(a) v (b) $\frac{v}{2}$ (c) $\frac{v}{3}$ (d) $\frac{v}{4}$

27. A body of mass 5 kg is moving with a momentum of 10 $kg\ ms^{-1}$. Now a force of 2 N acts on the body in the direction of its motion for 5s. The increase in the Kinetic energy of the body is _____ J.
[8 April, 2023 Shift-2)]

28. A body of mass M at rest explodes into three pieces, in the ratio of masses 1:1:2. Two smaller pieces fly off perpendicular to each other with velocities of 30 ms^{-1} and 40 ms^{-1} respectively. The velocity of the third piece will be:
[29 June, 2022 (Shift-I)]

(a) 15 ms^{-1} (b) 25 ms^{-1}
(c) 35 ms^{-1} (d) 50 ms^{-1}

29. Two blocks of masses 10 kg and 30 kg are placed on the same straight line with coordinates (0, 0) and (x, 0) respectively. The block of 10 kg is moved on the same line through a distance of 6 cm towards the other block. The distance through which the block of 30 kg must be moved to keep the position of centre of mass of the system unchanged is
[27 June, 2022 (Shift-I)]

(a) 4 cm towards the 10 kg block
(b) 2 cm away from the 10 kg block
(c) 2 cm towards the 10 kg block
(d) 4 cm away from the 10 kg block

30. A man of 60 kg is running on the road and suddenly jumps into stationary trolly car of mass 120 kg. Then, the trolly car starts moving with velocity 2 ms^{-1}. The velocity of the running man was _____ ms^{-1}, when he jumps into the car:
[28 June, 2022 (Shift-I)]

31. A block moving horizontally on a smooth surface with a speed of 40 m/s splits into two parts with masses in the ratio of 1:2. If the smaller part moves at 60 m/s in the same direction, then the fractional change in kinetic energy is:
[31 Aug, 2021 (Shift-II)]

(a) 2/3 (b) 1/3
(c) 1/4 (d) 1/8

32. A block moving horizontally on a smooth surface with a speed of 40 ms^{-1} splits into two equal parts. If one of the parts moves at 60 ms^{-1} in the same direction, then the fractional change in the kinetic energy will be $x : 4$ where x = _____.
[31 Aug, 2021 (Shift-I)]

33. A particle of mass m is moving with speed 2 v collides with a mass 2m moving with speed v in the same direction. After collision, the first mass is stopped completely while the second one splits into two particles each of mass m, which move at angle 45° with respect to the original direction. The speed of each of the moving particle will be:
[9 April, 2019 (Shift-II)]

(a) $v/(2\sqrt{2})$ (b) $2\sqrt{2}v$ (c) $\sqrt{2}v$ (d) $v/\sqrt{2}$

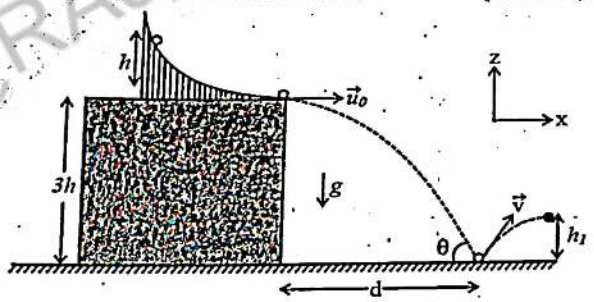
34. A bullet of '4 g' mass is fired from a gun of mass 4 kg. If the bullet moves with the muzzle speed of 50 ms^{-1}, the impulse imparted to the gun and velocity of recoil of gun are:
[22 July, 2021 (Shift-II)]

(a) 35.....4kg ms^{-1}, 0.1ms^{-1} (b) 0.2 kg ms^{-1}, 0.05 ms^{-1}
(c) 36.....4 kg ms^{-1}, 0.05 ms^{-1} (d) 0.2 kg ms^{-1}, 0.1ms^{-1}

Collisions (Oblique and Head on)

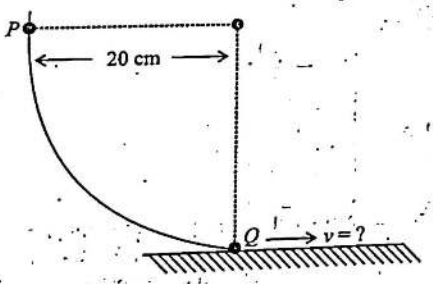
35. A body starts falling freely from height H hits an inclined plane in its path at height h. As a result of this perfectly elastic impact, the direction of the velocity of the body becomes horizontal. The value of $\frac{H}{h}$ for which the body will take the maximum time to reach the ground is _____.
[31 Jan, 2024 (Shift-I)]

36. A slide with a frictionless curved surface, which becomes horizontal at its lower end, is fixed on the terrace of a building of height $3h$ from the ground, as shown in the figure. A spherical ball of mass m is released on the slide from rest at a height h from the top of the terrace. The ball leaves the slide with a velocity $\vec{u}_0 = u_0 \hat{x}$ and falls on the ground at a distance d from the building making an angle θ with the horizontal. It bounces off with a velocity $\vec{v}$ and reaches a maximum height h_1. The acceleration due to gravity is g and the coefficient of restitution of the ground is $\frac{1}{\sqrt{3}}$. Which of the following statements is/are correct?
[JEE Adv, 2023]



(a) $\vec{u}_0 = \sqrt{2gh}\,\hat{x}$ (b) $\vec{v} = \sqrt{2gh}\,(\hat{x} - \hat{z})$
(c) $\theta = 60°$ (d) $\frac{d}{h_1} = 2\sqrt{3}$

37. As per the given figure, a small ball P slides down the quadrant of a circle and hits the other ball Q of equal mass which is initially at rest. Neglecting the effect of friction and assume the collision to be elastic, the velocity of ball Q after collision will be: ($g = 10\ m/s^2$)
[30 Jan, 2023 (Shift-I)]



(a) 0 (b) 25 m/s
(c) 2 m/s (d) 4 m/s

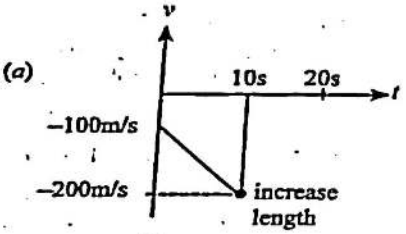
SNAKE_CBSE X @RATED_DUNE

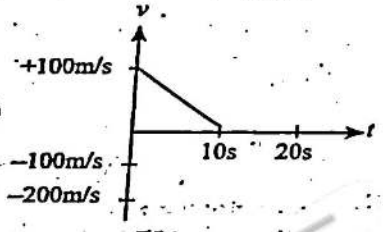
38. A ball of mass 200 g rests on a vertical post of height 20 m. A bullet of mass 10 g, travelling in horizontal direction, hits the centre of the ball. After collision both travels independently. The ball hits the ground at a distance 30 m and the bullet at a distance of 120 m from the foot of the post. The value of initial velocity of the bullet will be (if $g = 10\ m/s^2$): [30 Jan, 2023 (Shift-I)]
(a) 120 m/s (b) 60 m/s (c) 400 m/s (d) 360 m/s

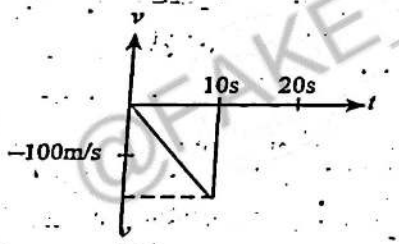
39. A ball is dropped from a height of 20 m. If the coefficient of restitution for the collision between ball and floor is 0.5, after hitting the floor, the ball rebounds to a height of _____ m.
[31 Jan, 2023 (Shift-II)]

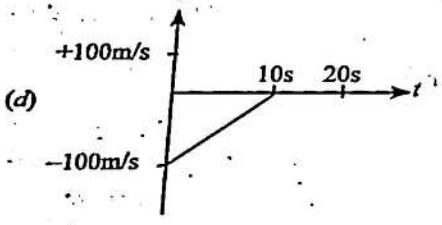
40. A body of mass 1 kg collides head on elastically with a stationary body of mass 3 kg. After collision, the smaller body reverses its direction of motion and moves with a speed of 2m/s. The initial speed of the smaller body before collision is _____ ms^{-1}.
[25 Jan, 2023 (Shift-II)]

41. A bullet is shot vertically downwards with an initial velocity of 100 m/s from a certain height. Within 10s, the bullet reaches the ground and instantaneously comes to rest due to the perfectly inelastic collision. The velocity -time curve for total time $t = 20$ s will be: (Take $g = 10 m/s^2$). [27 July, 2022 (Shift-I)]

(a)


(b)


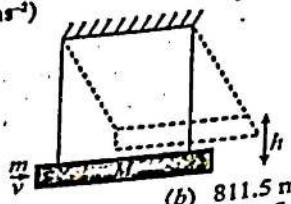
(c)


(d)


What percentage of kinetic energy of a moving particle is transferred to a stationary particle when it strikes the stationary particle of 5 times its mass? (Assume the collision to be head-on elastic collision)
[27 June, 2022 (Shift-I)]
(a) 43.....0 % (b) 66.6 % (c) 55.5 % (d) 33.3 %

43. A rubber ball is released from a height of 5 m above the floor. It bounces back repeatedly, always rising to $\frac{81}{100}$ of the height through which it falls. Find the average speed of the ball. (Take $g = 10\ ms^{-2}$) [17 March, 2021 (Shift-II)]
(a) 44...50 ms^{-1} (b) 3.0 ms^{-1} (c) 2.0 ms^{-1} (d) 3.50 ms^{-1}

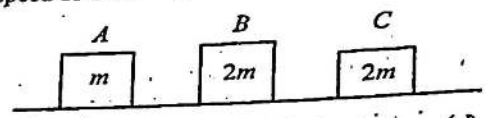
44. A large block of wood of mass $M = 5.99$ kg is hanging from two long massless cords. A bullet of mass $m = 10$ g is fired into the block and gets embedded in it. The (block + bullet) then swing upward, their centre of mass rising a vertical distance $h = 9.8$ cm before the (block + bullet) pendulum comes momentarily to rest at the end of its arc. The speed of the bullet just before collision is: [16 March, 2021 (Shift-II)]
(take $g = 9.8\ ms^{-2}$)



(a) 46.....5 m/s (b) 811.5 m/s
(c) 841.5 m/s (d) 47.....5 m/s

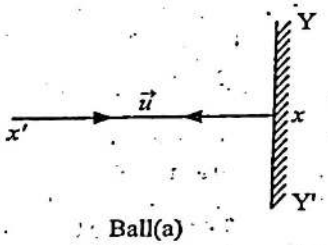
45. Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R.
Assertion A : Body 'P' having mass M moving with speed 'u' has head - on collision elastically with another body 'Q' having mass 'm' initially at rest. If $m << M$, Body will have a maximum speed equal to '2u' after collision.
Reason R : During elastic collision, the momentum and kinetic energy are both conserved. In the light of the above statements, choose the most appropriate answer from the options given below:
[26 Feb, 2021 (Shift-I)]
(a) A is correct but R is not correct.
(b) A is not correct but R is correct.
(c) Both A and R are correct and R is the correct explanation of A
(d) Both A and R correct but R is not the correct explanation of A

46. Three objects A, B and C are kept in a straight line on a frictionless horizontal surface. The masses of A, B and C are m, 2 m and 2 m respectively. A moves towards B with a speed of 9 m/s and makes an elastic collision with it. Thereafter B makes a completely inelastic collision with C. All motions occur along same straight line. The final speed of C is: [27 July, 2021 (Shift-I)]

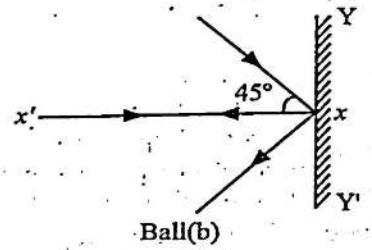


(a) 4 m/s (b) 6 m/s (c) 9 m/s (d) 3 m/s

47. Two billiard balls of equal mass 30g strike a rigid wall with same speed of 108 kmph (as shown) but at different angles. If the balls get reflected with the same speed then the ratio of the magnitude of impulses imparted to ball 'a' and ball 'b' by the wall along 'X' direction is: [25 July, 2021 (Shift-I)]



Ball(a)



Ball(b)

(a) $\sqrt{2}:1$ (b) $1:\sqrt{2}$ (c) 1 : 1 (d) 2 : 1

@FAKE_CBSE X @RANKBOOST

48. A body of mass M moving at speed V_0 collides elastically with a mass m at rest. After the collision, the two masses move at angles θ_1 and θ_2 with respect to the initial direction of motion of the body of mass M. The largest possible value of the ratio M/m, for which the angles θ_1 and θ_2 will be equal, is: **[31 Aug, 2021 (Shift-I)]**

(a) 3 (b) 1 (c) 2 (d) 4

49. An object of mass m_1 collides with another object of mass m_2, which is at rest. After collision the objects move with equal speeds in the opposite direction. The ratio of the masses $m_2 : m_1$ is:

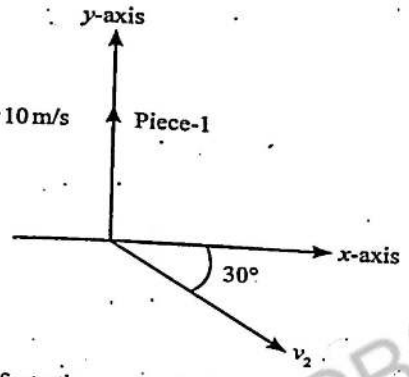
[18 March, 2021 (Shift-II)]

(a) 1 : 1 (b) 3 : 1 (c) 1 : 2 (d) 2 : 1

50. A ball of mass 10kg, moving with a velocity $10\sqrt{3}$m/s along, the x-axis, hits another ball of mass 20kg which is at rest. After the collision, first ball comes to rest while second ball disintegrates into two equal pieces. One piece starts moving along y–axis with a speed of 10 m/s. The second piece starts moving at an angle of 30° with respect to the x-axis.

The velocity of the ball moving at 30° with x-axis is x m/s.

The configuration of pieces after collision is shown in the figure below.



The value of x to the nearest integer is _____.

[18 March, 2021 (Shift-I)]

51. A ball with a speed of 9 m/s collides with another identical ball at rest. After the collision the direction of each ball makes an angle of 30° with the original direction. The ratio of velocities of the balls after collision is $x : y$, where x is_____.

[24 Feb, 2021 (Shift-I)]

52. A body of mass 2 kg moving with a speed of 4 m/s. makes an elastic collision with another body at rest and continues to move in the original direction but with one fourth of its initial speed. The speed of the two body centre of mass is $\frac{x}{10}$ m/s. The value of x is_____.

[25 July, 2021 (Shift-I)]

53. A bullet of 10 g, moving with velocity v, collides head-on with the stationary bob of a pendulum and recoils with velocity 100 m/s. The length of the pendulum is 0.5 m and mass of the bob is 1 kg. The minimum value of $v =$ _____ m/s so that the pendulum describes a circle. (Assume the string to be inextensible and $g = 10$ m/s^2)

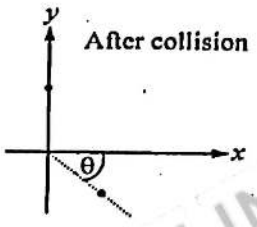
[27 Aug, 2021 (Shift-II)]

54. A ball of mass 10 kg moving with a velocity $10\sqrt{3}$ms^{-1} along X–axis, hits another ball of mass 20 kg which is at rest. After collision, the first ball comes to rest and the second one disintegrates into two equal pieces. One of the pieces starts moving along Y–axis at a speed of 10m/s. The second piece starts moving at a speed of 20m/s at an angle 0 (degree) with respect to the X–axis.

The configuration of pieces after collision is shown in the figure.

The value of 0 to the nearest integer is _____.

[16 March, 2021 (Shift-I)]



55. A block of mass 1.9 kg is at rest at the edge of a table, of height 1m. A bullet of mass 0.1 kg collides with the block and sticks to it. If the velocity of the bullet is 20 m/s in the horizontal direction just before the collision then the kinetic energy just before the combined system strikes the floor, is

[Take $g = 10$ m/s^2. Assume there is no rotational motion and loss of energy after the collision is negligible.] **[3 Sep, 2020 (Shift-II)]**

(a) 19 J (b) 23 J (c) 20 J (d) 21 J

56. Two particles of equal mass m have respective initial velocities $u\hat{i}$ and $u\left(\frac{\hat{i}+\hat{j}}{2}\right)$. They collide completely inelastically. The energy lost in the process is **[9 Jan, 2020 (Shift-I)]**

(a) $\frac{3}{4}mu^2$ (b) $\sqrt{\frac{2}{3}}mu^2$ (c) $\frac{1}{3}mu^2$ (d) $\frac{1}{8}mu^2$

57. A particle of mass m is projected with a speed u from the ground at an angle $\theta = \pi/3$ w.r.t. horizontal ($x-$axis). When it has reached its maximum height, it collides completely inelastically with another particle of the same mass and velocity $u\hat{i}$. The horizontal distance covered by the combined mass before reaching the ground is:

[9 Jan, 2020 (Shift-II)]

(a) $\frac{3\sqrt{3}}{8}\frac{u^2}{g}$ (b) $2\sqrt{2}\frac{u^2}{g}$ (c) $\frac{5}{8}\frac{u^2}{g}$ (d) $\frac{3\sqrt{2}}{4}\frac{u^2}{g}$

58. A particle of mass m is dropped from a height h above the ground. At the same time another particle of the same mass is thrown vertically upwards from the ground with a speed of $\sqrt{2gh}$. If they collide head-on completely inelastically, the time taken for the combined mass to reach the ground, in units of $\sqrt{\frac{h}{g}}$ is:**[8 Jan, 2020 (Shift-II)]**

(a) $\frac{1}{2}$ (b) $\sqrt{\frac{1}{2}}$ (c) $\sqrt{\frac{3}{4}}$ (d) $\sqrt{\frac{3}{2}}$

@FREE_CBSE_IIT_JEE_NEET

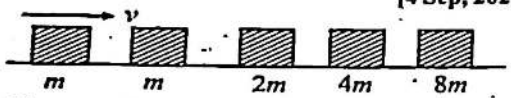
59. Particle A of mass m_1 moving with velocity $(\sqrt{3}\hat{i}+\hat{j})$ ms^{-1} collides with another particle B of mass m_2 which is at rest initially. Let $\vec{v}_1$ and $\vec{v}_2$ be the velocities of particles A and B after collision respectively. If $m_1 = 2m_2$ and after collision $\vec{v}_1 = (\hat{i}+\sqrt{3}\hat{j})$ ms^{-1}, the angle between $\vec{v}_1$ and $\vec{v}_2$ is [6 Sep, 2020 (Shift-II)]

(a) $-45°$ (b) $60°$ (c) $15°$ (d) $105°$

60. A particle of mass m with an initial velocity $u\hat{i}$ collides perfectly elastically with a mass $3m$ at rest. It moves with a velocity $v\hat{j}$ after collision, then, v is given by [2 Sep, 2020 (Shift-I)]

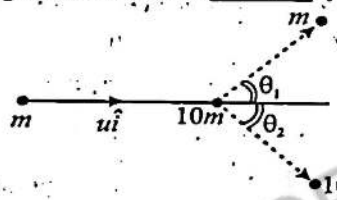
(a) $v = \frac{1}{\sqrt{6}}u$ (b) $v = \frac{u}{\sqrt{3}}$ (c) $v = \sqrt{\frac{2}{3}}u$ (d) $v = \frac{u}{\sqrt{2}}$

61. Blocks of masses m, $2m$, $4m$ and $8m$ are arranged in a line on a frictionless floor. Another block of mass m, moving with speed v along the same line (see figure) collides with mass m in perfectly inelastic manner. All the subsequent collisions are also perfectly inelastic. By the time the last block of mass $8m$ starts moving, the total energy loss is p% of the original energy. Value of 'p' is close to [4 Sep, 2020 (Shift-I)]



(a) 37 (b) 77 (c) 87 (d) 94

62. A particle of mass m is moving along the x-axis with initial velocity $u\hat{i}$. It collides elastically with a particle of mass $10m$ at rest and then moves with half its initial kinetic energy(see figure). If $\sin\theta_1 = \sqrt{n}\sin\theta_2$, then value of n is _____. [2 Sep, 2020 (Shift-II)]



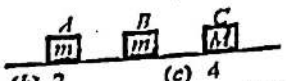
63. Two bodies of the same mass are moving with the same speed, but in different directions in a plane. They have a completely inelastic collision and move together thereafter with a final speed which is half of their initial speed.
The angle between the initial velocities of the two bodies (in degree) is _____. [6 Sep, 2020 (Shift-I)]

64. A body A of mass $m = 0.1$ kg has an initial velocity of $3\hat{i}$ ms^{-1}. It collides elastically with another body B of the same mass which has an initial velocity of $5\hat{j}$ ms^{-1}. After collision, A moves with a velocity $\vec{v} = 4(\hat{i}+\hat{j})$ m/s. The energy of B after colision is written as $\frac{x}{10}$ J.
The value of x is _____. [8 Jan, 2020 (Shift-I)]

65. A body of mass m_1 moving with an unknown velocity o $v_1\hat{i}$ undergoes a collinear collision with a body of mass m_2 moving with a velocity $v_2\hat{i}$. After collision, m_1 and m_2 move with velocities of $v_3\hat{i}$ and $v_4\hat{i}$, respectively. If $m_2 = 0.5\, m_1$ and $v_3 = 0.5\, v_1$, then v_1 is : [8 April, 2019 (Shift-II)]

(a) $v_4 - \frac{v_2}{4}$ (b) $v_4 - \frac{v_2}{2}$ (c) $v_4 - v_2$ (d) $v_4 + v_2$

66. Three blocks A, B and C are lying on a smooth horizontal surface as shown in the figure. A and B have equal masses, m while C has mass M. Block A is given an initial speed v towards B due to which it collides with B perfectly inelastically. The combined mass collides with C, also perfectly inelastically if $\frac{5}{6}$th of the initial kinetic energy is lost in whole process. What is value of M/m? [9 Jan, 2019 (Shift-I)]

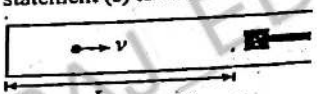


(a) 5 (b) 2 (c) 4 (d) 3

67. A body of mass 2 kg makes an elastic collision with a second body at rest and continues to move in the original direction but with one fourth of its original speed. What is the mass of the second body? [9 April, 2019 (Shift-I)]

(a) 68....5 kg (b) 1.2 kg (c) 1.8 kg (d) 1.0 kg

68. A small particle of mass m moving inside a heavy, hollow and straight tube along the tube axis undergoes elastic collision at two ends. The tube has no friction and it is closed at one end by a flat surface while the other end is fitted with a heavy movable flat piston as shown in figure. When the distance of the piston from closed end is $L = L_0$, the particle speed is $v = v_0$. The piston is moved inward at a very low speed V such that $V << \frac{dL}{L}v_0$ where dL is the infinitesimal displacement of the piston. Which of the following statement (s) is/are correct? [JEE Adv, 201



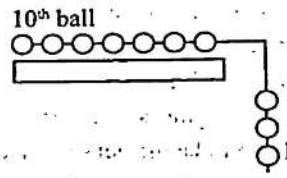
(a) The rate at which the particle strikes the piston is v/L
(b) After each collision with the piston, the particle speed increases by $2V$
(c) The particle's kinetic energy increases by a factor of 4 when the piston is moved inward from L_0 to $\frac{1}{2}L_0$
(d) If the piston moves inward by dL, the particle speed increases by $2v\frac{dL}{L}$

69. A particle of mass m is moving with speed 2 v collides with a mass 2m moving with speed v in the same direction. After collision, the first mass is stopped completely while the second one splits into two particles each of mass m, which move at angle 45° with respect to the original direction. The speed of each of the moving particle will be: [9 April, 2019 (Shift-II)]

(a) $v/(2\sqrt{2})$ (b) $2\sqrt{2}v$ (c) $\sqrt{2}v$ (d) $v/\sqrt{2}$

Variable Mass Systems

70. A system to 10 balls each of mass 2kg are connected via massless and unstretchable string. The system is allowed to slip over the edge of a smooth table as shown in figure. Tension on the string between the 7th and 8th ball is _____ N when 6th ball just leaves the table. [26 June, 2022 (Shift-II)]



@FALLCRSE X @RAJ EDUCATION

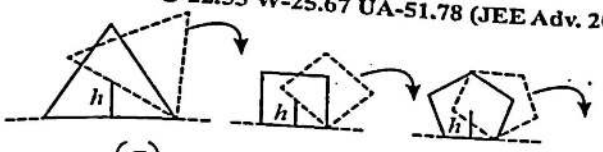
JEE-Advanced

Displacement, Velocity, Acceleration of Com

Single Correct

1. Consider regular polygons with number of sides $n = 3,4,5.....$ as shown in the figure. The centre of mass of all the polygons is at height h from the ground. They roll on a horizontal surface about the leading vertex without slipping and sliding as depicted. The maximum increase in height of the locus of the centre of mass for each polygon is Δ. Then, Δ depends on n and h as

C-22.55 W-25.67 UA-51.78 (JEE Adv. 2017)



(a) $\Delta = h\sin^2\left(\frac{\pi}{n}\right)$ (b) $\Delta = h\sin\left(\frac{2\pi}{n}\right)$

(c) $\Delta = h\tan^2\left(\frac{\pi}{2n}\right)$ (d) $\Delta = h\left(\frac{1}{\cos\left(\frac{\pi}{n}\right)} - 1\right)$

2. Look at the drawing given in the figure, which has been drawn with ink of uniform line-thickness. The mass of ink used to draw each of the two inner circles, and each of the two line segments is m. The mass of the ink used to draw the outer circle is 6 m. The coordinates of the centres of the different parts are : outer circle (0, 0), left inner circle $(-a, a)$, right inner circle (a, a), vertical line (0, 0) and horizontal line $(0, -a)$. The y-coordinate of the centre of mass of the ink in this drawing is (IIT-JEE 2009)

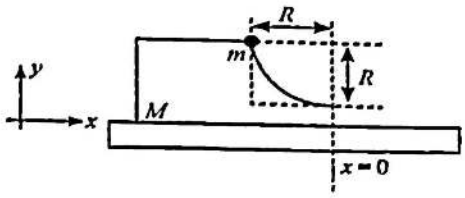
(a) $\frac{a}{10}$ (b) $\frac{a}{8}$ (c) $\frac{a}{12}$ (d) $\frac{a}{3}$

3. Two particles A and B initially at rest, move towards each other by mutual force of attraction. At the instant when the speed of A is v and the speed of B is $2v$, the speed of the centre of mass of the system is (IIT-JEE 1982)

(a) $3v$ (b) v (c) $1.5v$ (d) zero

Multiple Correct

4. A block of mass M has a circular cut with a frictionless surface as shown. The block rests on the horizontal frictionless surface of a fixed table. Initially the right edge of the block is at $x = 0$, in a coordinate system fixed to the table. A point mass m is released from rest at the topmost point of the path as shown and it slides down. When the mass loses contact with the block, its position is x and the velocity is v. At that instant, which of the following options is/are correct? C-9.62 W-21.65 UA-52.96 PC-15.78 (JEE Adv. 2017)



(a) The velocity of the point mass m is $v = \sqrt{\frac{2gR}{1+\frac{m}{M}}}$

(b) The x component of displacement of the centre of mass of the block M is $-\frac{mR}{M+m}$

(c) The position of the point mass is $x = -\sqrt{2}\frac{mR}{M+m}$

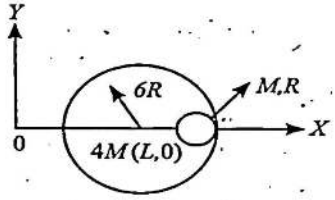
(d) The velocity of the block M is $V = -\frac{m}{M}\sqrt{2gR}$

True/False

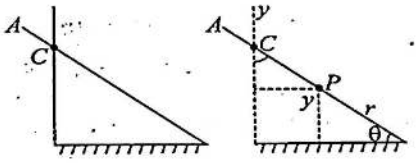
5. Two particles of mass 1 kg and 3 kg move towards each other under their mutual force of attraction. No other force acts on them. When the relative velocity of approach of the two particles is 2 m/s, their centre of mass has a velocity of 0.5 m/s. When the relative velocity of approach becomes 3 m/s, the velocity of the centre of mass is 0.75 m/s. (IIT-JEE 1989)

Subjective

6. A small sphere of radius R is held against the inner surface of a larger sphere of radius $6R$. The masses of large and small spheres are $4M$ and M respectively. This arrangement is placed on a horizontal table. There is no friction between any surfaces of contact. The small sphere is now released. Find the coordinates of the centre of the larger sphere when the smaller sphere reaches the other extreme position. (IIT-JEE 1996)



7. A uniform thin rod of mass M and length L is standing vertically along the y-axis on a smooth horizontal surface, with its lower end at the origin (0, 0). A slight disturbance at $t = 0$ causes the lower end to slip on the smooth surface along the positive x-axis, and the rod starts falling.

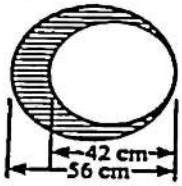


@FAST_CLASSX@GMAIL.COM

(a) What is the path followed by the centre of mass of the rod during its fall?

(b) Find the equation of the trajectory of a point on the rod located at a distance r from the lower end. What is the shape of the path of this point?. **(IIT-JEE 1993)**

8. A circular plate of uniform thickness has a diameter of 56 cm. A circular portion of diameter 42 cm is removed from one edge of the plate as shown in figure.
Find the position of the centre of mass of the remaining portion. **(IIT-JEE 1980)**



Law of Conservation of Momentum

Single Correct

9. An object of mass 5 kg is projected with a velocity of 60° at an angle of 20 m/s to the horizontal. At the highest point of its path, the projectile explodes and breaks up into two fragments of masses 1 kg and 4 kg. The fragments separate horizontally after the explosion. The explosion releases internal energy such that the kinetic energy of the system at the highest point is doubled. Calculate the separation between the two fragments when they reach the ground. **(IIT-JEE 1990)**

(a) 40.25 m (b) 35.25 m (c) 44.25 m (d) 41.25 m

10. A shell is fired from a cannon with a velocity $V(m/s)$ at an angle θ with the horizontal direction. At the highest point in its path it explodes into two pieces of equal mass. One of the pieces retraces its path to the cannon and the speed (m/s) of the other pieces immediately after the explosion is **(IIT-JEE 1986)**

(a) $3V\cos\theta$ (b) $2V\cos\theta$ (c) $\frac{3}{2}V\cos\theta$ (d) $\sqrt{\frac{3}{2}}V\cos\theta$

Multiple Correct

11. Two balls, having linear momenta $p_1 = p\hat{i}$ and $p_2 = -p\hat{i}$, undergo a collision in free space. There is no external force acting on the balls. Let p_1' and p_2' be their final momentum. The following option figure (s) is (are) not allowed for any non-zero value of $p, a_1, a_2, b_1, b_2, c_1$ and c_2. **(IIT-JEE 2008)**

(a) $p_1' = a_1\hat{i} + b_1\hat{j} + c_1\hat{k},\ p_2' = a_2\hat{i} + b_2\hat{j}$

(b) $p_1' = c_1\hat{k},\ p_2' = c_2\hat{k}$

(c) $p_1' = a_1\hat{i} + b_1\hat{j} + c_1\hat{k},\ p_2' = a_2\hat{i} + b_2\hat{j} - c_1\hat{k}$

(d) $p_1' = a_1\hat{i} + b_1\hat{j},\ p_2' = a_2\hat{i} + b_1\hat{j}$

Fill in the Blanks

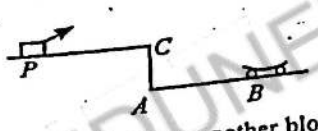
12. A particle of mass $4m$ which is at rest explodes into three fragments. Two of the fragments each of mass m are found to move with a speed v each in mutually perpendicular directions. The total energy released in the process of explosion is _____ **(IIT-JEE 1987)**

True/False

13. Two particles of masses 1 kg and 3 kg move towards each other under their mutual force of attraction. No other force acts on them. When the relative velocity of approach of the two particles is 2 m/s, their centre of mass has a velocity of 0.5 m/s. When the relative velocity of approach becomes 3 m/s, the velocity of the centre of mass is 0.75 m/s. **(IIT-JEE 1989)**

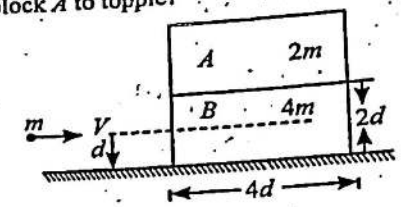
Subjective

14. A car P is moving with a uniform speed of $5\sqrt{3}$ m/s towards a carriage of mass 9 kg at rest kept on the rails at a point B as shown in figure. The height AC is 120 m. Cannon balls of 1 kg are fired from the car with an initial velocity 100 m/s at an angle 30° with the horizontal. The first cannon ball hits the stationary carriage after a time t_0 and sticks to it. Determine t_0. At t_0, the second cannonball is fired. Assume that the resistive force between the rails and the carriage is constant and ignore the vertical motion of the carriage throughout.
If the second ball also hits and sticks to the carriage, what will be the horizontal velocity of the carriage just after the second impact? **(IIT-JEE 2011)**



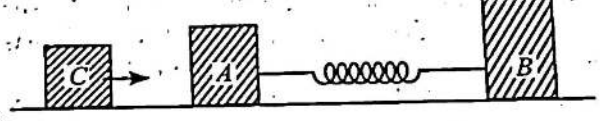
15. A block A of mass 2 m is placed on another block B of mass 4 m which in turn is placed on a fixed table. The two blocks have a same length $4d$ and they are placed as shown in figure. The coefficient of friction (both static and kinetic) between the block B and table is μ. There is no friction between the two blocks. A small object of mass m moving horizontally along a line passing through the center of mass (CM) of the block B and perpendicular to its face with a speed v collides elastically with the block B at a height $2d$ above the table.

(a) What is the minimum value of v (call it v_0) required to make the block A to topple?



(b) If $v = 2v_0$, find the distance (from the point P in the figure) at which the mass m falls on the table after collision. (Ignore the role of friction during the collision.) **(IIT-JEE 199**

16. Two bodies A and B of masses m and $2m$ respectively are placed on a smooth floor. They are connected by a spring. A third body C of mass m moves with velocity v_0 along the line joining A and B and collides elastically with A as shown in figure. At a certain instant of time t_0 after collision, it is found that the instantaneous velocities of A and B are the same. Further at this instant the compression of the spring is found to be x_0. Determine (a) the common velocity of A and B at time t_0 and (b) the spring constant. **(IIT-JEE 198**



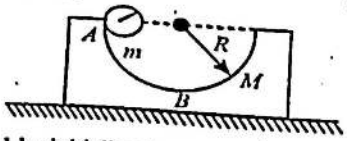
BREAKE CODEX @ TELEGRAM.NET

17. A block of mass M with a semicircular track of radius R, rests on a horizontal frictionless surface. A uniform cylinder of radius r and mass m is released from rest at the top point A (see fig.). The cylinder slips on the semicircular frictionless track.

A. How far has the block moved when the cylinder reaches the bottom (point) of the track?

B. How fast is the block moving when the cylinder reaches the bottom of the track?

(IIT-JEE 1983)

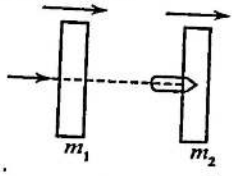


18. A body of mass 1 kg initially at rest, explodes and breaks into three fragments of masses in the ratio 1 : 1 : 3. The two pieces of equal mass fly-off perpendicular to each other with a speed of 30 m/s each. What is the velocity of the heavier fragment?

(IIT-JEE 1981)

19. A 20g bullet pierces through a plate of mass $M_1 = 1$ kg and then comes to rest inside a second plate of mass $M_2 = 2.98$ kg as shown in the figure. It is found that the two plates initially at rest, now move with equal velocities. Find the percentage loss in the initial velocity of the bullet when it is between M_1 and M_2. Neglect any loss of material of the plates due to the action of the bullet. Both plates are lying on a smooth table.

(IIT-JEE 1979)



20. When a ball is thrown up, the magnitude of its momentum decreases and then increases. Does this violate the conservation of momentum principle?

(IIT-JEE 1979)

21. A body of mass moving with a velocity in the x-direction collides with another body of mass M moving in the y-direction with a velocity V. They coalesce into one body during collision. Find

(a) the direction and magnitude of the momentum of the composite body.

(b) the fraction of the initial kinetic energy transformed into heat during the collision.

(IIT-JEE 1978)

Impulse

Single Correct

22. A solid horizontal surface is covered with a thin layer of oil. A rectangular block of mass $m = 0.4$ kg is at rest on this surface. An impulse of 1.0 N s is applied to the block at time $t = 0$, so that it starts moving along the X-axis with a velocity $v(t) = v_0 e^{-t/\tau}$, where v_0 is a constant and $\tau = 4$ s. The displacement of the block, in meters, at $t = \tau$ is (Take, $e^{-1} = 0.37$).

C-7.43 W-75.89 UA-16.68 (JEE Adv. 2018)

(a) 3 (b) 4 (c) 5 (d) 6

23. Two blocks of masses 10 kg and 4 kg are connected by a spring of negligible mass and placed on a frictionless horizontal surface. An impulse gives a velocity of 14 m/s to the heavier block in the direction of the lighter block. The velocity of the centre of mass is

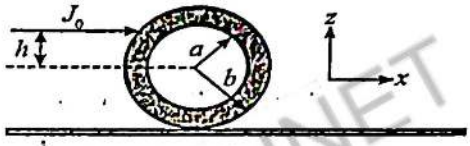
(IIT-JEE 2002)

(a) 30 m/s (b) 20 m/s (c) 10 m/s (d) 5 m/s

Multiple Correct

24. An annular disk of mass M, inner radius a and outer radius b is placed on a horizontal surface with coefficient of friction μ, as shown in the figure. At some time, an impulse $J_0\hat{x}$ is applied at a height h above the center of the disk. If $h = h_m$ then the disk rolls without slipping along the x-axis. Which of the following statement(s) is(are) correct?

C-1.17 W-0 UA-57.98 PC-40.84 (JEE Adv. 2023)



(a) For $\mu \neq 0$ and $a \to 0$, $h_m = b/2$

(b) For $\mu \neq 0$ and $a \to b$, $h_m = b$

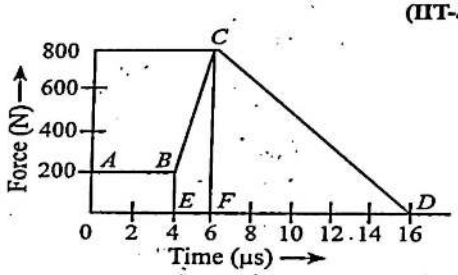
(c) For $h = h_m$, the initial angular velocity does not depend on the inner radius a.

(d) For $\mu = 0$ and $h = 0$. the wheel always slides without rolling.

Numerical Types/Integer Types

25. The magnitude of the force (in Newtons) acting on a body varies with time t (in microseconds as shown in the figure. AB, BC and CD are straight line segments. The magnitude of the total impulse of the force on the body from $t = 4\mu s$ to $t = 16\mu s$ is _____ N – s.

(IIT-JEE 1994)



Collisions

Single Correct

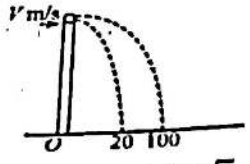
26. A particle of mass m is projected from the ground with an initial speed u_0 at an angle α with the horizontal. At the highest point of its trajectory, it makes a completely inelastic collision with another identical particle, which was thrown vertically upward from the ground with the same initial speed u_0. The angle that the composite system makes with the horizontal immediately after the collision is

C-21.77 W-73.71 UA-4.52 (JEE Adv. 2013)

(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{4}+\alpha$ (c) $\frac{\pi}{4}-\alpha$ (d) $\frac{\pi}{2}$

@FREE JEE X @RAJ_PUNET

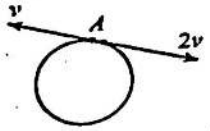
27. A ball of mass 0.2 kg rests on a vertical post of height 5 m. A bullet of mass 0.01 kg, traveling with a velocity v m/s in a horizontal direction, hits the centre of the ball. After the collision, the ball and bullet travel independently. The ball hits the ground at a distance of 20 m and the bullet at a distance of 100 m from the foot of the post. The initial velocity v of the bullet is (IIT-JEE 2011)



(a) 250 m/s (b) $250\sqrt{2}$ m/s

(c) 400 m/s (d) 500 m/s

28. Two small particles of equal masses start moving in opposite directions from a point A in a horizontal circular orbit. Their tangential velocities are v and $2v$ respectively, as shown in the figure. Between collisions, the particles move with constant speeds. After making how many elastic collisions, other than that at A, these two particles will again reach the point A? (IIT-JEE 2009)



(a) 4 (b) 3 (c) 2 (d) 1

29. **Statement-I:** In an elastic collision between two bodies, the relative speed of the bodies after collision is equal to the relative speed before the collision.

Statement-II: In an elastic collision, the linear momentum of the system is conserved. (IIT-JEE 2007)

Mark your answer as

(a) If Statement-I is true, Statement-II is true, Statement-II is the correct explanation for Statement-I

(b) If Statement-I is true, Statement-II is true; Statement-II is not a correct explanation for Statement-I

(c) If Statement-I is true; Statement-II is false

(d) If Statement-I is false; Statement-II is true

30. Two particles of masses m_1 and m_2 in projectile motion have velocities v_1 and v_2 respectively at time $t = 0$. They collide at time t_0. Their velocities become v_1' and v_2' at time $2t_0$ while still moving in the air. The value of $|(m_1v_1' + m_2v_2') - (m_1v_1 + m_2v_2)|$ is (IIT-JEE 2001)

(a) Zero (b) $(m_1 + m_2)gt_0$

(c) $2(m_1 + m_2)gt_0$ (d) $\frac{1}{2}(m_1 + m_2)gt_0$

31. A ball hits the floor and rebounds after an inelastic collision. In this case, (IIT-JEE 1986)

(a) The momentum of the ball just after the collision is the same as that just before the collision

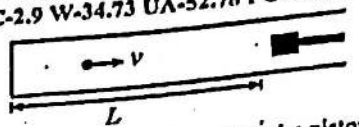
(b) The mechanical energy of the ball remains the same in the collision

(c) The total momentum of the ball and the earth is conserved

(d) The total mechanical energy of the ball and the earth is conserved

Multiple Correct

32. A small particle of mass m moving inside a heavy, hollow and straight tube along the tube axis undergoes elastic collision at two ends. The tube has no friction and it is closed at one end by a flat surface while the other end is fitted with a heavy movable flat piston as shown in figure. When the distance of the piston from closed end is $L = L_0$, the particle speed is $v = v_0$. The piston is moved inward at a very low speed V such that $V << \frac{dL}{L}v_0$ where dL is the infinitesimal displacement of the piston. Which of the following statement(s) is/are correct? C-2.9 W-34.73 UA-52.78 PC-9.58 (JEE Adv. 2013)



(a) The rate at which the particle strikes the piston is v/L

(b) After each collision with the piston, the particle speed increases by $2V$

(c) The particle's kinetic energy increases by a factor of 4 when the piston is moved inward from L_0 to $\frac{1}{2}L_0$

(d) If the piston moves inward by dL, the particle speed increases by $2v\frac{dL}{L}$

33. A point mass of 1 kg collides elastically with a stationary point mass of 5 kg. After their collision, the 1 kg mass reverses its direction and moves with a speed of 2 ms^{-1}. Which of the following statement(s) is/are correct for the system of these two masses? (IIT-JEE 2010)

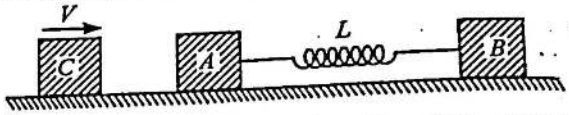
(a) Total momentum of the system is 3 kg ms^{-1}

(b) Momentum of mass after collision is 4 kg ms^{-1}

(c) Kinetic energy of the centre of mass is 0.75 J

(d) Total kinetic energy of the system is 4 J

34. Two blocks A and B each of mass m, are connected by a massless spring of natural length L and spring constant k. The blocks are initially resting on a smooth horizontal floor with the spring at its natural length, as shown in figure. A third identical block C, also of mass m, moves on the floor with a speed v along the line joining A and B, and collides elastically with A. Then (IIT-JEE 1999)



(a) The kinetic energy of the $A - D$ system, at maximum compression of the spring, is zero

(b) The kinetic energy of the $A - B$ system, at maximum compression of the spring, is $mv^2/4$

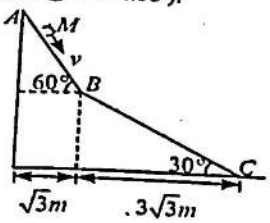
(c) The maximum compression of the spring is $v\sqrt{(m/k)}$

(d) The maximum compression of the spring is $v\sqrt{\frac{m}{2k}}$

@RAJEDUNET

Comprehension Based/Passage Based

Direction (Q. 35 to 37): A small block of mass M moves on a frictionless surface of an inclined plane, as shown in figure. The angle of the incline suddenly changes from 60° to 30° at point B. The block is Match the Column initially at rest at A. Assume that collisions between the block and the incline are totally inelastic ($g = 10$ m/s²). **(IIT-JEE 2008)**



35. The speed of the block at point immediately after it strikes the second incline is

(a) $\sqrt{60}$ m/s (b) $\sqrt{45}$ m/s (c) $\sqrt{30}$ m/s (d) $\sqrt{15}$ m/s

36. The speed of the block at point , immediately before it leaves the second incline is

(a) $\sqrt{120}$ m/s (b) $\sqrt{105}$ m/s (c) $\sqrt{90}$ m/s (d) $\sqrt{75}$ m/s

37. If collision between the block and the incline is completely elastic, then the vertical (upward) component of the velocity of the block at point, immediately after it strikes the second incline is

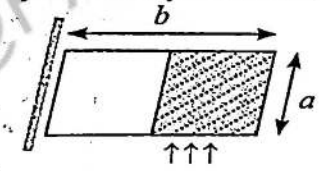
(a) $\sqrt{30}$ m/s (b) $\sqrt{15}$ m/s (c) zero (d) $-\sqrt{15}$ m/s

Numerical Types/Integer Types

38. A ball is projected from the ground at an angle of 45° with the horizontal surface. It reaches a maximum height of 120 m and returns to the ground. Upon hitting the ground for the first time, it loses half of its kinetic energy. Immediately after the bounce, the velocity of the ball makes an angle of 30° with the horizontal surface. The maximum height it reaches after the bounce, in meters, is **C-31.93 W-59 UA-9.07 (JEE Adv. 2018)**

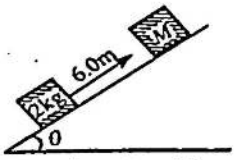
Subjective

39. There is a rectangular plate of mass M kg of dimensions $(a \times b)$. The plate is held in horizontal position by striking n small balls uniformly each of mass m per unit area per unit time. These are striking in the shaded half region of the plate. The balls are colliding elastically with velocity v. What is v? **(IIT-JEE 2006)**



It is given $n = 100$, $M = 3$ kg, $m = 0.01$ kg
$b = 2$ m; $a = 1$ m; $g = 10$ m/s²

40. Two blocks of mass 2 kg and M are at rest on an inclined plane and are separated by a distance of 6.0 m as shown. The coefficient of friction between each block and the inclined plane is 0.25. The 2 kg block is given a velocity of 10.0 m/s up the inclined plane. It collides with M, comes back and has a velocity of 1.0 m/s when it reaches its initial position. The other block M after the collision moves 0.05 m up and comes to rest. Calculate the coefficient of restitution between the blocks and the mass of the block M. **(IIT-JEE 1999)**



[Take $\sin\theta = \tan\theta = 0.05$ and $g = 10$ m/s²]

41. A cylindrical solid of mass 10^{-2} kg and cross-sectional area 10^{-4} m² is moving parallel to its axis (the x-axis) with a uniform speed of 10^1 m/s in the positive direction. At $t = 0$, its front face passes the plane $x = 0$. The region to the right of this plane is filled with stationary dust particles of uniform density 10^{-3} kg/m³. When a dust particle collides with the face of the cylinder, it sticks to its surface. Assuming that the dimensions of the cylinder remain practically unchanged and that the dust sticks only to the front face of the cylinder find the x-coordinate of the front of the cylinder at $t = 150$ s. **(IIT-JEE 1998)**

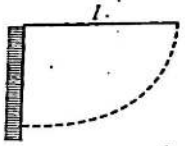
42. A cart is moving along x-direction with a velocity of 4 m/s. A person on the cart throws a stone with a velocity of 6 m/s relative to himself. In the frame of reference of the cart, the stone is thrown in y-z plane making an angle of 30° with vertical z-axis. At the highest point of its trajectory, the stone hits an object of equal mass hung vertically from branch of a tree by means of a string of length L.

A completely inelastic collision occurs, in which the stone gets embedded in the object. Determine ($g = 9.82$ m/s²) **(IIT-JEE 1997)**

(a) the speed of the combined mass immediately after the collision with respect to an observer on the ground.

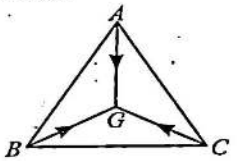
(b) the length L of the string such that tension in the string becomes zero when the string becomes horizontal during the subsequent motion of the combined mass.

43. A simple pendulum is suspended from a peg on a vertical wall. The pendulum is pulled away from the wall to a horizontal position (see fig.) and released. The ball hits the wall, the coefficient of restitution being $\frac{2}{\sqrt{5}}$. What is the minimum number of collisions after which the amplitude of oscillations becomes less than 60°? **(IIT-JEE 1987)**



44. A ball of mass 100 g is projected vertically upwards from the ground with a velocity of 49 m/s. At the same time, another identical ball is dropped from a height of 98 m to fall freely along the same path as that followed by the first ball. After some time, the two balls collide and stick together and finally fall to the ground. Find the time of flight of the masses. **(IIT-JEE 1985)**

45. Three particles A,B and C of equal mass move with equal speed v along the medians of an equilateral triangle as shown in figure. They collide at the centroid G of the triangle. After the collision, A comes to rest, B retraces its path with the speed v. What is the velocity of C after collision? **(IIT-JEE 1982)**



@IITE-CBSE@RAJDOWRY

ANSWER KEY

JEE-Main

1. [3]	2. [15]	3. [8]	4. (a)	5. [2]	6. [4]	7. (c)	8. (c)	9. (b)	10. (a)
11. [03]	12. [23]	13. (d)	14. (a)	15. (d)	16. (d)	17. [2]	18. [3]	19. (c)	20. (c)
21. (d)	22. (a)	23. (a)	24. (d)	25. (a)	26. (c)	27. [30]	28. (b)	29. (c)	30. [6]
31. (d)	32. [1]	33. (b)	34. (b)	35. [2]	36. (a, c, d)	37. (c)	38. (d)	39. [5]	40. [4]
41. (a)	42. (c)	43. (a)	44. (a)	45. (c)	46. (d)	47. (a)	48. (a)	49. (b)	50. [20]
51. [1]	52. [25]	53. [400]	54. [30]	55. (d)	56. (d)	57. (a)	58. (d)	59. (d)	60. (d)
61. (d)	62. [10]	63. [120]	64. [1]	65. (c)	66. (c)	67. (b)	68. (b, c)	69. (b)	70. [36]

JEE-Advanced

1. (d)	2. (a)	3. (d)	4. (a,b)	5. [False]	9. (c)	10. (a)	11. (a, d)	13. [False]	22. (d)
23. (c)	24. (a, b, c, d)	25. [0.005]	26. (a)	27. (d)	28. (c)	29. (b)	30. (c)	31. (c)	32. (b, c)
33. (a, c)	34. (b, d)	35. (b)	36. (b)	37. (c)	38. [30]				

EXPLANATIONS

JEE-Main

1. [3] Position vector $\vec{r}_{COM}$

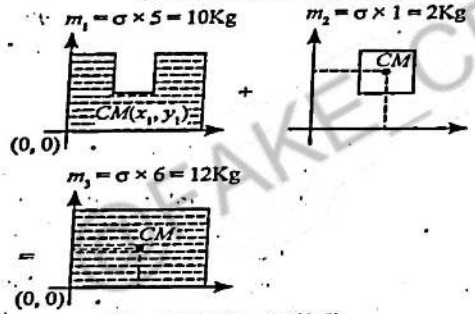
$$= \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + m_3\vec{r}_3}{m_1 + m_2 + m_3}$$

$$\vec{r} = \frac{4}{3}\hat{i} + \frac{4}{3}\hat{j} = \frac{4\sqrt{2}}{3}$$

Hence, $x = 3$

2. [15] $m_1 = \sigma \times 5 = 10$ Kg

(σ is surface mass density)



$$\Rightarrow 10x_1 + 2(1.5) = 12(1.5)$$

$$= 10 \times 1 = 18 - 3/10 \Rightarrow x_1 = 1.5 \text{ cm}$$

$$\Rightarrow m_1y_1 + m_2y_2 = m_3y_3$$

$$10y_1 + 2(1.5) = 12 \times 1 \Rightarrow y_1 = 0.9 \text{ cm}$$

$$\frac{x_1}{y_1} = \frac{1.5}{0.9} = \frac{15}{9}$$

$$n = 15$$

3. [8] Linear mass density,

$$\lambda = \lambda_0\left(1 - \frac{x^2}{L^2}\right) \text{kg/m}$$

$$m = \int \lambda dx = \int_0^L \lambda_0\left(1 - \frac{x^2}{L^2}\right)dx$$

$$= \lambda_0\left(L - \frac{L^3}{3L^2}\right) = \frac{2L\lambda_0}{3}$$

$$X_C = \frac{1}{m}\int x\,dm = \frac{1}{m}\int_0^L x\lambda_0\left(1 - \frac{x^2}{L^2}\right)dx$$

$$= \frac{\lambda_0}{m}\left[\frac{x^2}{2} - \frac{x^4}{4L^2}\right]_0^L = \frac{3}{8}L$$

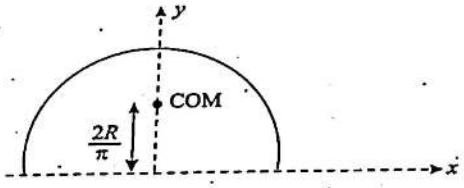
As, $X_C = \frac{3L}{\alpha} = \frac{3}{8}L \Rightarrow \alpha = 8$

4. (a) $$x_{COM} = \frac{(\sigma\pi^2 a)a - \sigma\pi\left(\frac{a}{2}\right)^2 \cdot \left(\frac{3a}{2}\right)}{\sigma\pi^2 a - \sigma\pi\left(\frac{a}{2}\right)^2}$$

$$= \frac{a - \frac{3a}{8}}{1 - \frac{1}{4}} = \frac{5a}{6}$$

5. [2] Location of COM $= \left(0, \frac{2R}{\pi}\right)$

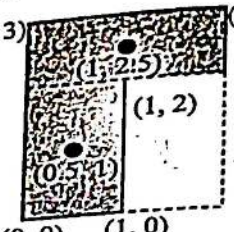
Hence $|x| = 2$.



6. [4] $x_{cm} = y_{cm} = \frac{4a}{3\pi}$

$\therefore x = 4$

7. (c)



$$\vec{r}_{cm} = \frac{2 \times \left(\frac{\hat{i}}{2} + \hat{j}\right) + 2 \times \left(\hat{i} + \frac{5\hat{j}}{2}\right)}{2 + 2}$$

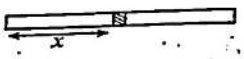
$$\Rightarrow \vec{r}_{cm} = \frac{3}{4}\hat{i} + \frac{7}{4}\hat{j}$$

8. (c) From 1 kg mass,

$$x_{COM} = \frac{1(0) + 2.5(0) + 1.5(3)}{1 + 2.5 + 1.5} = \frac{4.5}{5} = 0.9$$

$$y_{COM} = \frac{1(0) + 2.5(4) + 1.5(0)}{1 + 2.5 + 1.5} = 2 \text{ cm}$$

9. (b)



$$x_{cm} = \frac{1}{M}\int_0^L x.dM$$

$$dM = \lambda.dx = \left(a + b\left(\frac{x}{L}\right)^2\right).dx$$

BREAKE CBSE X @RAJ_EDUNET

$$x_{cm}=\frac{\int x dM}{\int dM}=\frac{\int x\lambda dx}{\int \lambda dx}=\frac{\int_0^L x\left(a+\frac{bx^2}{L^2}\right)dx}{\int_0^L\left(a+\frac{bx^2}{L^2}\right)dx}$$

$$=\frac{a\left(\frac{x^2}{2}\right)_0^L+\frac{b}{L^2}\left(\frac{x^4}{4}\right)_0^L}{a(x)_0^L+\frac{b}{L^2}\left(\frac{x^3}{3}\right)_0^L}$$

$$=\frac{a\frac{L^2}{2}+b\frac{L^2}{4}}{aL+\frac{bL}{3}}=\frac{(2a+b)}{(3a+b)}\frac{L}{4}\times 3$$

$$=\frac{3L}{4}\left(\frac{2a+b}{3a+b}\right)$$

10. (a) $M_1=\frac{4}{3}\pi R^3\rho$ & $M_2=\frac{4}{3}\pi(1)^3(-\rho)$

$$X_{com}=\frac{M_1X_1+M_2X_2}{M_1+M_2}$$

$$\Rightarrow \frac{\left[\frac{4}{3}\pi R^3\rho\right]0+\left[\frac{4}{3}\pi(1)^3(-\rho)\right][R-1]}{\frac{4}{3}\pi R^3\rho+\frac{4}{3}\pi(1)^3(-\rho)}$$

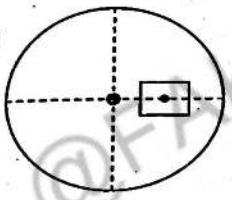
$$\Rightarrow \frac{(R-1)}{(R^3-1)}=(2-R) \qquad (R\neq 1)$$

$$\frac{(R-1)}{(R-1)(R^2+R+1)}=2-R$$

$$(R^2+R+1)(2-R)=1$$

11. [03] $x=\frac{3R}{8}=3cm$

12. [23]



Let the density is σ

Then original mass $m_0=\pi a^2\sigma$

Remaining mass $m'=\left(\pi a^2-\frac{a^2}{4}\right)\sigma$

$$=a^2\left(\frac{4\pi-1}{4}\right)\sigma$$

Removed mass $m=\frac{a^2}{4}.\sigma$

$$\therefore \pi a^2\sigma(0)=\frac{a^2}{4}.\sigma\times\frac{a}{2}+\frac{\sigma a^2}{4}(4\pi-1)r$$

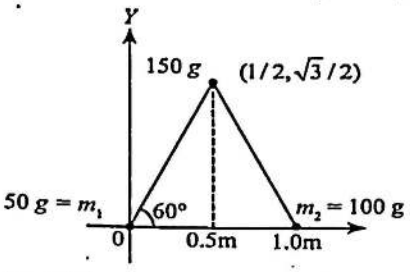
$$\Rightarrow r=\frac{-a}{2(4\pi-1)}=\frac{-a}{23.13}=\frac{-a}{23}$$

13. (d) $\vec{r}_{cm}=\frac{m_1\vec{r}_1+m_2\vec{r}_2+m_3\vec{r}_3}{m_1+m_2+m_3}$

$$\vec{r}_{cm}=\frac{0+150\times\left(\frac{1}{2}\hat{i}+\frac{\sqrt{3}}{2}\hat{j}\right)+100\times\hat{i}}{300}$$

$$\vec{r}_{cm}=\frac{7}{12}\hat{i}+\frac{\sqrt{3}}{4}\hat{j}$$

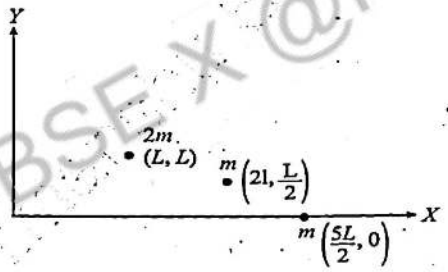
∴Co-ordinate of center $=\left(\frac{7}{12},\frac{\sqrt{3}}{4}\right)m$



14. (a) Let consider the rod in three parts of masses $2m$, m and m. $\vec{r}_1=L\hat{i}+L\hat{j}$

$$\vec{r}_2=2L\hat{i}+\frac{L}{2}\hat{j} \quad \vec{r}_3=\frac{5L}{2}\hat{i}$$

Three parts of rod can be considered as point masses.



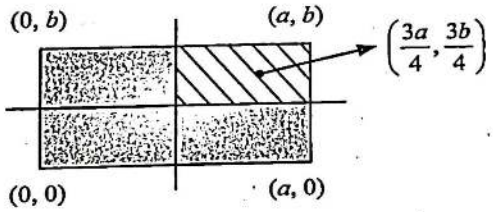
Now, position vector of COM,

$$\vec{r}_{cm}=\frac{2m\vec{r}_1+m\vec{r}_2+m\vec{r}_3}{4m}$$

$$\vec{r}_{cm}=\frac{2m\left(L\hat{i}+L\hat{j}\right)+m\left(2L\hat{i}+\frac{L}{2}\hat{j}\right)+m\left(\frac{5L}{2}\hat{i}\right)}{4m}$$

$$=\frac{13}{8}L\hat{i}+\frac{5}{8}L\hat{j}$$

15. (d)



Area of complete sheet $(A_1)=ab$

Area of shaded part $(A_2)=\frac{ab}{4}$

For centre of mass,

$$X_{cm}=\frac{A_1X_1-A_2X_2}{A_1-A_2}=\frac{ab\left(\frac{a}{2}\right)-\frac{ab}{4}\left(\frac{3a}{4}\right)}{ab-\frac{ab}{4}}$$

$$X_{cm}=\frac{5a}{12}$$

$$Y_{cm}=\frac{A_1Y_1-A_2Y_2}{A_1-A_2}=\frac{ab\left(\frac{a}{2}\right)-\frac{ab}{4}\left(\frac{3b}{4}\right)}{ab-\frac{ab}{4}}$$

$$Y_{cm}=\frac{5b}{12}$$

So, the coordinate of centre of mass (remaining sheet)

$$(X_{cm},Y_{cm})=\left(\frac{5a}{12},\frac{5b}{12}\right)$$

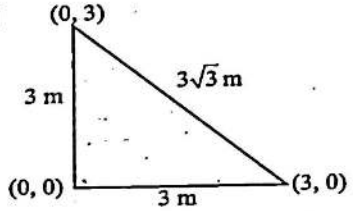
16. (d) The position vector centre of mass

$$\vec{r}=\frac{m_1\vec{r}_1+m_2\vec{r}_2}{m_1+m_2}$$

$$\vec{r}=\frac{1(\hat{i}+2\hat{j}+\hat{k})+3(-3\hat{i}-2\hat{j}+\hat{k})}{1+3}$$

$$=-2\hat{i}-\hat{j}+\hat{k}$$

17. [2]



$$\vec{r}_{com}=\frac{m(0\hat{i}+0\hat{j})+m(3\hat{i})+m(3\hat{j})}{3m}$$

$$\vec{r}_{com}=\hat{i}+\hat{j}\Rightarrow|\vec{r}_{com}|=\sqrt{2}=\sqrt{x}\Rightarrow x=2$$

18. [3] $\Delta X_{C.O.M.}=\frac{m_1\Delta x_1+m_2\Delta x_2}{m_1+m_2}$

$$\Rightarrow 0=\frac{3\times 2+2(-x)}{3+2}\Rightarrow x=3\text{cm}$$

19. (c) Y_{cm}, from ground

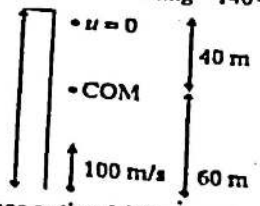
$$=\frac{m_1y_1+m_2y_2}{m_1+m_2}=\frac{0.03\times 100}{0.05}=60\text{m}$$

$$\mu_{cm}=\frac{m_1\mu_1+m_2\mu_2}{m_1+m_2}=\frac{0.02\times 100}{0.05}=40\text{m/s}$$

$$H=\frac{\mu_{cm}^2}{2g}=\frac{40\times 40}{20}=80\text{m}$$

@FAKE_CBSE_X @RAJ_EDUFET

Maximum height of CM = H + 60
= 80 + 60 = 140
Weight above building = 140 − 100 = 40 m



Hence option (c) is correct answer.

20. (c) For position of COM to remain unchanged,
$m_1x_1 = m_2x_2 \Rightarrow 10 \times 6 = 30 \times x_2$
$\Rightarrow x_2 = 2$ cm towards 10 kg block.

21. (d) The position vector centre of mass

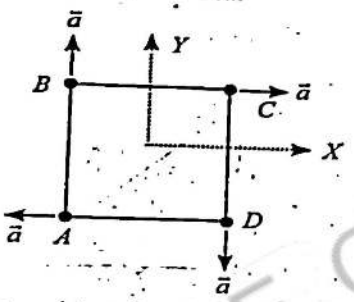
$$\vec{r} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1 + m_2}$$

$$\vec{r} = \frac{1(\hat{i}+2\hat{j}+\hat{k}) + 3(-3\hat{i}-2\hat{j}+\hat{k})}{1+3}$$

$$= -2\hat{i} - \hat{j} + \hat{k}$$

22. (a) $\vec{a}_{cm} = \frac{m_A\vec{a}_A + m_B\vec{a}_B + m_C\vec{a}_C + m_D\vec{a}_D}{m_A + m_B + m_C + m_D}$

$$\vec{a}_{cm} = \frac{-ma\hat{i} + 2m\hat{j} + 3ma\hat{i} - 4ma\hat{j}}{10m}$$



$$\vec{a}_{cm} = \frac{a}{5}\hat{i} - \frac{a}{5}\hat{j} = \frac{a}{5}(\hat{i} - \hat{j})$$

23. (a) v_1 ← [50] Man [20] Son → v_2
$\Rightarrow 0 = 50v_1 - 20v_2$ and $v_1 + v_2 = 0.7$
$\Rightarrow v_1 = 0.20$ m/s

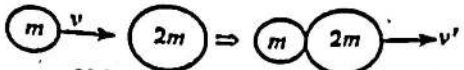
24. (d) According to conservation of momentum
$1000 \times 6 = 1200 \times v$
$v = 5$ m/s

25. (a) We have given that the
Initial momentum is zero.
Hence momentum will be conserved
$\Rightarrow m_Av_B = m_BV_B$
Ratio of the kinetic energy of both the particle

$$\frac{(KE)_A}{(KE)_B} = \frac{\frac{1}{2}m_Av_A^2}{\frac{1}{2}m_Bv_B^2} = \frac{v_A}{v_B}$$

$$\frac{(KE)_B}{(KE)_A} = \frac{v_B}{v_A}$$

26. (c)



Using conservation of linear momentum
⇒ Initial momentum = Final Momentum
$mv + 2m \times 0 = (m + 2m)v'$
$\therefore mv = 3mv'$
$v' = \frac{v}{3}$

27. [30] Given
$m = 5$ kg
$P_1 = 10$ kg m/s (initial momentum)
From impulse momentum theorem
$F\Delta t = \Delta P = P_f - P_i$
$2 \times 5 = P_2 - 10$
$P_2 = 20$ kg m/s (final momentum)
Increase in $KE = KE_2 - KE_1$

$$= \frac{P_2^2}{2m} - \frac{P_1^2}{2m}$$

$$= \frac{1}{2\times 5} \times (400 - 100) = 40 - 10 = 30J$$

28. (b) After explosion, let $m_1 = M/4$
(M = initial mass)
$v_1 = 30\hat{i}$ m/s
$m_2 = M/4$, $v_2 = 40\hat{j}$ m/s
$m_3 = M/2$, $v_3 = v$
Since momentum is conserved,
$\vec{P}_1 + \vec{P}_2 + \vec{P}_3 = 0$, $\vec{P}_3 = -(\vec{P}_1 + \vec{P}_2)$
As $\vec{P}_1$ & $\vec{P}_2$ are perpendicular,
$\therefore P_3 = \sqrt{P_1^2 + P_2^2} = \frac{50M}{4} = \frac{M}{2}v$
so, $v = 25$

29. (c) For position of COM to remain unchanged,
$m_1x_1 = m_2x_2 \Rightarrow 10 \times 6 = 30 \times x_2$
$\Rightarrow x_2 = 2$ cm towards 10 kg block.

30. [6] From the conservation of momentum:
$p_i = p_f$
$60 \times v = (60 + 120) \times 2 \Rightarrow v = 6$ m/s

31. (d) $\xrightarrow{v_0}$ [3 m] → $\xrightarrow{v_2}$ [2 m] $\xrightarrow{v_1}$ [m]
Using conservation of linear momentum:
$3mv_0 = 2mv_2 + mv_1$
$\Rightarrow 40 \times 3m = 60 \times m + v_2 \times 2m$
$\Rightarrow v_2 = 30$ m/s

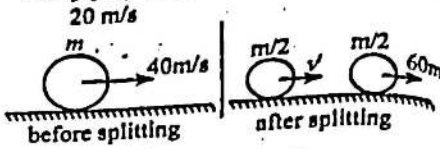
$$KE_i = \frac{1}{2} \times 3m \times (40)^2$$

$$KE_f = \frac{1}{2} \times m \times (60)^2 + \frac{1}{2} \times 2m \times (30)^2$$

$$\Rightarrow \frac{KE_f}{KE_i} = \frac{54}{48}$$

Hence, Fractional change in kinetic energy $= 1 - \frac{KE_f}{KE_i} = \frac{1}{8}$.

32. [1] By momentum conservation v
20 m/s



$$KE_f = \frac{1}{2}\frac{m}{2}\left[v'^2 + 60^2\right]$$

$$= \frac{1}{2}\frac{m}{2}\left(20^2 + 60^2\right)$$

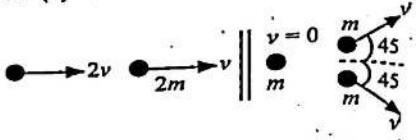
$$= \frac{1}{2}m(2000)$$

$$\frac{\Delta KE}{KE} = \frac{\frac{1}{2}m(2000) - \frac{1}{2}m(1600)}{\frac{1}{2}m(1600)}$$

$$= \frac{\frac{1}{2}m(400)}{\frac{1}{2}m(1600)} = \frac{1}{4} = \frac{x}{4} \therefore x = 1$$

Hence, value of x is 1.

33. (b)



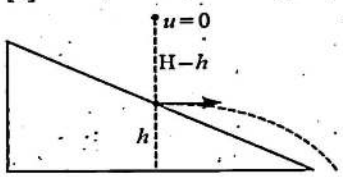
Using linear momentum conservation

$$m2v + 2mv = m \times 0 + m\frac{v'}{\sqrt{2}} \times 2$$

$$4mv = \frac{2mv'}{\sqrt{2}} \Rightarrow v' = 2\sqrt{2}v$$

34. (b) Using momentum conservation.
$4 \times 10^{-3}(50 - v) - 4v = 0$
$v = 0.05$ m/s
Impule, $J = mv = 4 \times 0.05$
$J = 0.2$ kg m/s

35. [2]



@FAKE_CBSE_@RAJ_EDUNET

Total time of flight = T

$$T=\sqrt{\frac{2h}{g}}+\sqrt{\frac{2(H-h)}{g}}$$

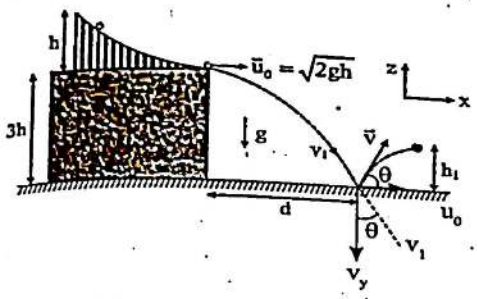
For max. time $=\frac{dT}{dh}=0$

$$\sqrt{\frac{2}{g}}\left(\frac{-1}{2\sqrt{H-h}}+\frac{1}{2\sqrt{h}}\right)=0$$

$$\sqrt{H-h}=\sqrt{h}$$

$$h=\frac{H}{2}\Rightarrow\frac{H}{h}=2$$

36. *(a, c, d)*



Applying the conservation of energy for height

$$h\,0+mgh=\frac{1}{2}mu_0^2+0$$

$$u_0=\sqrt{2gh}$$

$$\vec{u}_0=\sqrt{2gh}\,\hat{x}$$

Again, applying conservation of energy for height $3h$.

$$mg(3h)=\frac{1}{2}mv_y^2 \qquad (\text{Along}-\hat{y})$$

$$\therefore v_y=\sqrt{2g(3h)}$$

$$\therefore \vec{v}_1=u_0\hat{x}-v_y\hat{z}=\sqrt{2gh}\,\hat{x}-\sqrt{2g3h}\,\hat{z}$$

$$\vec{v}=u_0\hat{x}+ev_y\hat{z}$$

$$\vec{v}=\sqrt{2gh}\,\hat{x}+\sqrt{2g3h}\times\frac{1}{\sqrt{3}}\hat{z}$$

$$=\sqrt{2gh}\,\hat{x}+\sqrt{2gh}\,\hat{z}$$

$$\tan\theta=\frac{\sqrt{2g3h}}{\sqrt{2gh}}=\sqrt{3},\theta=60°$$

$$h_1=\frac{v_{1y}^2}{2g}=\frac{2gh}{2g}=h$$

$$d=v_x t=\sqrt{2gh_1}\times\sqrt{\frac{2\times3h_1}{g}}$$

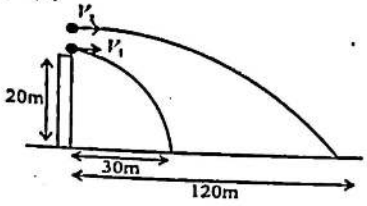
$$=\sqrt{2gh_1}\sqrt{\frac{6h_1}{g}}=2\sqrt{3h_1}=\frac{d}{h_1}=2\sqrt{3}$$

37. *(c)* The velocities will be interchanged after collision.

Speed of P just before collision $=\sqrt{2gh}$

$$=\sqrt{2\times10\times0.2}=2\,m/s$$

38. *(d)*

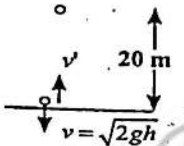


$$v_1=\frac{30}{\sqrt{\frac{2h}{g}}},v_2=\frac{120}{\sqrt{\frac{2h}{g}}}$$

$$(0.01)u=(0.2)\frac{30\sqrt{g}}{\sqrt{2h}}+(0.01)\frac{120\sqrt{g}}{\sqrt{2h}}$$

$$u=300+60=360\,ms^{-1}$$

39. [5]



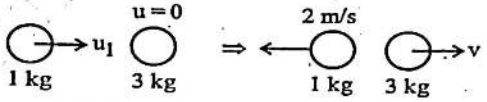
$$h'=\frac{(v')^2}{2g}=\frac{e^2v^2}{2g}=e^2h$$

[Given, $e=0.5$, $h=20$m]

$$=(0.5)^2\times20$$

$$=5\text{m}$$

40. [4]



Using conservation of linear momentum,

$$1\times u_1=-2+3v$$

$$\Rightarrow u_1=-2+3v \qquad ...(i)$$

Coefficient of restitution $e=\frac{v_2-v_1}{u_1-u_2}$

$$\Rightarrow 1=\frac{v+2}{u_1}$$

$$\Rightarrow v+2=u_1 \qquad ...(ii)$$

Solving (i) and (ii)

$$u_1=4\text{ m/s}$$

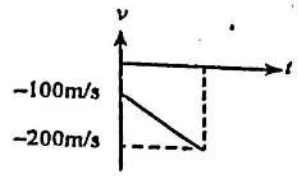
41. *(a)* From Kinematics equations.

$v=u+at$

$v=-100-10t$

at, $t=0$, $v=-100-10\times0=-100$ m/s

at $t=10$ s, $v=-100-10\times10=-200$ m/s



42. *(c)* For a head on elastic collision

$$v_2=\frac{mu_1}{m+5m}+\frac{mu_1}{m+5m}=\frac{u_1}{3}$$

Initial kinetic energy of first mass:

$$K=\frac{1}{2}mu_1^2$$

Final kinetic energy of second mass

$$K'=\frac{1}{2}5m\left(\frac{u_1}{3}\right)^2=\frac{5}{9}\left(\frac{1}{2}mu_1^2\right)=\frac{5}{9}K$$

Percentage of energy transferred

$$=\frac{\frac{5}{9}K}{K}\times100=55.5\%$$

43. *(a)* Total distance,

$$d=h+2e^2h+2e^4h+2e^6h+2e^8h+.....$$

$$d=h+2e^2h\left(1+e^2+e^4+e^6+.....\right)$$

$$d=\frac{\left(1-e^2\right)k+2e^2k}{1-e^2}=\frac{k\left(1+e^2\right)}{1-e^2}$$

Total time

$$=T+2eT+2e_1^2T+2e^3T+.....$$

Total time

$$=T+2eT\left(1+e+e^2+e^3+.....\right)$$

$$=T+2eT\left(\frac{1}{1-e}\right)$$

Total time $=\frac{T(1+e)}{1-e}$

Average speed of the ball

$$=\frac{5}{1}\left(\frac{1+e^2}{(1+e)(1-e)}\frac{(1-e)}{(1+e)}\right)$$

$$V_{avg}=\frac{5\left(1+e^2\right)}{(1+e)^2}$$

$\because h^1=e^2h$

$$\frac{81}{100}=e^2\Rightarrow e=\frac{9}{10}=0.9$$

$$V_{avg}=\frac{5\left(1+(0.9)^2\right)}{(1+0.9)^2}=2.50\text{ m/sec.}$$

44. *(a)* $P_i=0.01\times u+0=P_f=6\times v$

$$v=\frac{0.01u}{6}$$

@FAKE_CBSE_X @RAJ_EDUNET

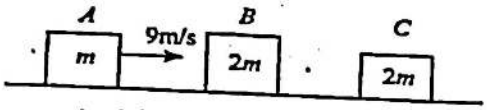
using energy conservation

$$\frac{1}{2}\times 6\times\left(\frac{u}{600}\right)^2 = 6\times 9.8\times 9.8\times 10^{-2}$$

$$\Rightarrow u = 6\times 98\times\sqrt{2} = 588\sqrt{2}\ \text{m/s}$$

45. (c) mass m will acquire velocity 2u. During collision, total momentum of system will be conserved but total kinetic energy is not conserved.

46. (d) Before collision, $u_A = 9$ m/s, $u_B = 0$
Let after collision velocities of A and B be v_A and v_B



Applying conservation of momentum,

$$m\times 9 + 2m\times = m\times v_A + 2mv_B$$

$$9 = v_A + 2v_B \qquad ...(i)$$

again, $e = \dfrac{v_B - v_A}{u_A - u_B}$

Since, collision is elastic, therefore $e = 1$

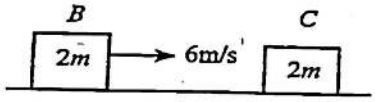
$$1 = \frac{v_B - v_A}{9-0}$$

$$9 = v_B - 2v_A \qquad ...(ii)$$

Solving (i) and (ii)

$v_B = 6$ m/s and $v_A = -3$ m/s

Now, applying conservation of momentum between B & C



$$2m\times 6 + 0 = (2m+2m)v_C$$

$$3\ \text{m/s} = v_C$$

47. (a) Applying the impulse momentum theorem

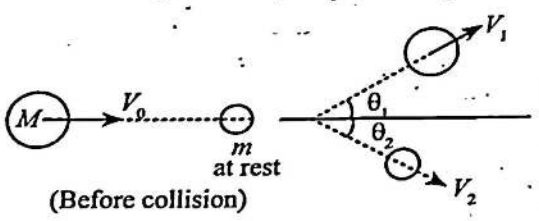
For ball (a): $I_1 = \Delta p_1 = 2mu$

Change in momentum,

For ball (b): $I_2 = \Delta p_2 = 2mu\cos 45°$

$$\frac{I_1}{I_2} = \frac{2mu}{2mu\cos 45°} = \sqrt{2}$$

48. (a) From momentum conservation in x-direction, $MV_0 = MV_1\cos\theta + MV_2\cos\theta$
and in y-direction, $MV_1\sin\theta - MV_2\sin\theta = 0$



(Before collision)

Solving above equation,

$$V_2 = \frac{MV_1}{m},\ V_0 = 2V_1\cos 0$$

From energy conservation

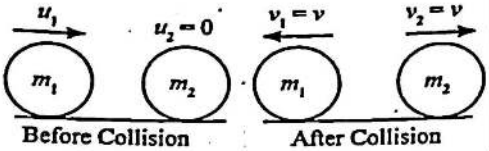
$$\frac{1}{2}MV_0^2 = \frac{1}{2}MV_1^2 + \frac{1}{2}mV_2^2$$

Substituting the value of V_2 and V_0

$$\frac{M}{m} + 1 = 4\cos^2 0 \le 4$$

$$\frac{M}{m} \le 3$$

49. (b)



Before Collision After Collision

Using conservation of linear momentum, we can write

$$m_1u = (m_2 - m_1)v \qquad ...(i)$$

With the help of definition of e, we can write

$$e = \frac{v_s}{v_a} = \frac{2v}{u} \Rightarrow u = \frac{2v}{e} \qquad ...(ii)$$

Putting the value of e in equation (i), we have

$$m_1\frac{2v}{e} = (m_2 - m_1)v \Rightarrow 2m_1 = em_2 - em_1$$

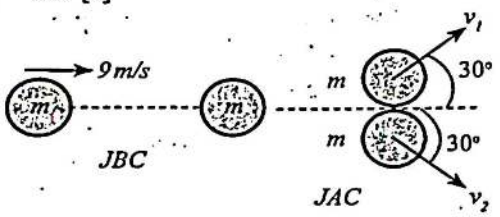
$$\Rightarrow \frac{m_2}{m_1} = \frac{2+e}{e} = 1 + \frac{2}{e} > 2$$

50. [20]
Apply conservation of momentum along y-axis

$$10\ v_1 = 10\ v_2\sin 30°$$

$$\Rightarrow v_2 = 20\ \text{m/s}.$$

51. [1]



Applying conservation of momentum in direction perpendicular to the original direction of motion,

$$mv_1\sin 30° = mv_2\sin 30°$$

$$\Rightarrow \frac{v_1}{v_2} = 1$$

52. [25] according to conservation of momentum principle.

$$P_i = P_f$$

$$\Rightarrow 2\times 4 = 2\times 1 + m_2\times v_2$$

$$\Rightarrow m_2v_2 = 6$$

From the coefficient of restitution

$$e = \frac{v_2 - v_1}{u_1 - u_2} \Rightarrow 1 = \frac{v_2 - 1}{4} \Rightarrow v_2 = 5\ \text{m/s}$$

So, $m_2 = 1.2$ kg

Now, $v_{cm} = \dfrac{m_1v_1 + m_2v_2}{m_1 + m_2}$

$$= \frac{2\times 1 + 1.2\times 5}{2+1.2} = \frac{8}{3.2} = \frac{25}{10}$$

$$\therefore x = 25$$

53. [400] Velocity of bob after collision,

$$v_1 = \sqrt{5gR} = \sqrt{5\times 10\times 0.5} = 5\text{m/s}$$

From conservation of momentum,

$$m_1v = m_2\times 5 - m_1\times 100$$

$$\frac{10}{1000}\times v = \frac{-10}{1000}\times 100 + 1\times 5$$

$$\therefore v = 400\text{m/s}$$

54. [30] It is given,
Velocity of ball before collision,

$$v_0 = 10\sqrt{3}ms^{-1}$$

Velocity of second ball after collision

$$v_2 = 20\ ms^{-1}$$

Using Conservation of linear momentum along x-axis, we can write

$$mv_0 = mv_2\cos\theta \Rightarrow \cos\theta = \frac{v_0}{v_2} = \frac{10\sqrt{3}}{20} = \frac{\sqrt{3}}{2}$$

$$\Rightarrow \theta = 30°$$

55. (d) Velocity of block after collision

$$= \frac{0.1\times 20}{1.9+0.1} = 1\ \text{m/s}$$

Kinetic energy just before striking the floor

$$= \frac{1}{2}Mv^2 + Mgh$$

$$= \frac{1}{2}\times 2\times 1^2 + 2\times 10\times 1 = 21\text{J}$$

56. (d) From the conservation of momentum

$$mu\hat{i} + m\left(\frac{u}{2}\hat{i} + \frac{u}{2}\hat{j}\right) = 2m(v_1\hat{i} + v_2\hat{j})$$

On solving, $v_1 = \dfrac{3u}{4}$ and $v_2 = \dfrac{u}{4}$

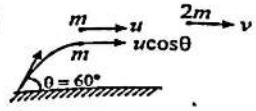
Change in K.E.

$$= \left[\frac{1}{2}mu^2 + \frac{1}{2}m\left(\frac{u}{2}\sqrt{2}\right)^2\right] - \left[\frac{1}{2}(2m)\left(\frac{9u^2}{16} + \frac{u^2}{16}\right)\right]$$

$$= \frac{3mu^2}{4} - \frac{5mu^2}{8} = \frac{mu^2}{8}$$

@TAKE_CBSE_X@RAJEEDIXIT

57. (a)



$p_i = p_f$

$mu + mu\cos\theta = 2mv$

$\Rightarrow v = \frac{u(1+\cos 60°)}{2} = \frac{3}{4}u$

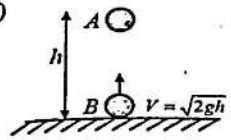
So horizontal range after collision

$= v\sqrt{\frac{2H_{max}}{g}}$

$= \frac{3}{4}u\sqrt{\frac{2u^2\sin^2(60°)}{2g^2}}$

$= \frac{3}{4}u^2\frac{\sqrt{\frac{3}{4}}}{g} = \frac{3\sqrt{3}u^2}{8g}$

58. (d)



Time for collision $t_1 = \frac{h}{\sqrt{2gh}}$

After t_1, $V_A = 0 - gt_1 = -\sqrt{\frac{gh}{2}}$

and $V_B = \sqrt{2gh} - gt_1 = \sqrt{gh}\left[\sqrt{2} - \frac{1}{\sqrt{2}}\right]$

At the time of collision $\vec{P}_i = \vec{P}_f$

$\Rightarrow m\vec{V}_A + m\vec{V}_B = 2m\vec{V}_f$

$\Rightarrow -\sqrt{\frac{gh}{2}} + \sqrt{gh}\left[\sqrt{2} - \frac{1}{\sqrt{2}}\right] = 2\vec{V}_f$

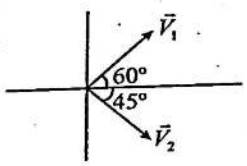
Thus, $V_f = 0$

And height from ground

$= h - \frac{1}{2}gt_1^2 = h - \frac{h}{4} = \frac{3h}{4}$

So time $= \sqrt{2\times\frac{\left(\frac{3h}{4}\right)}{g}} = \sqrt{\frac{3h}{2g}}$

59. (d)



$m_2 = m$ and $m_1 = 2m$

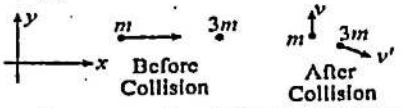
$\vec{p}_i = \vec{p}_f$

$\Rightarrow 2m\left(\sqrt{3}\hat{i} + \hat{j}\right) = 2m\left(\hat{i} + \sqrt{3}\hat{j}\right) + m\vec{V}_2$

$\Rightarrow \vec{V}_2 = \left(2\sqrt{3} - 2\right)\hat{i} - \hat{j}\left(2\sqrt{3} - 2\right)$

$\Rightarrow$ Angle $\theta = 105°$

60. (d)



By conservation of linear momentum

$3m\vec{v}' + mv\hat{j} = mu\hat{i} \Rightarrow \vec{V} = \frac{U}{3}\hat{i} - \frac{V}{3}\hat{j}$

By energy conservation

$\frac{1}{2}3mv'^2 + \frac{1}{2}mv^2 = \frac{1}{2}mu^2$

Eliminating v' gives

$v = \frac{u}{\sqrt{2}}$

61. (d) $\vec{P}_i = \vec{P}_f$

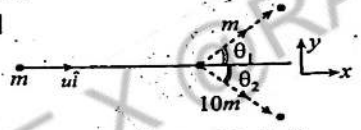
$\Rightarrow mv = (16\,m)v_0 \Rightarrow v_0 = \frac{v}{16}$

$\Rightarrow (\Delta KE)_{loss} = \frac{1}{2}mv^2 - \frac{1}{2}(16m)\left(\frac{v}{16}\right)^2$

$\Rightarrow \%\,Loss = \frac{(\Delta KE)_{Loss}}{\frac{1}{2}mv^2}\times 100 = \left(1 - \frac{1}{16}\right)\times 100$

$\approx 94\%$

62. [10]



Since energy of m reduced by half

$\therefore u_1 = \frac{u}{\sqrt{2}}$ and $\frac{1}{2}\times 10mv_1^2 = \frac{1}{2}\left(\frac{1}{2}mu^2\right)$

$\Rightarrow v_1 = \frac{u}{\sqrt{20}}$

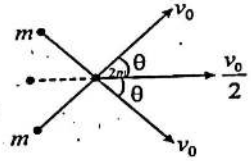
Now, momentum in y direction will remain conserved.

$\therefore mu_1\sin\theta_1 = 10mv_1\sin\theta_2$

$\Rightarrow \frac{u}{\sqrt{2}}\sin\theta_1 = 10\frac{u}{\sqrt{20}}\sin\theta_2$

$\Rightarrow \sin\theta_1 = \sqrt{10}\sin\theta_2$

63. [120] $mv_0 \times \cos\theta \times 2 = 2m\left(\frac{v_0}{2}\right)$



$\Rightarrow \cos\theta = \frac{1}{2}$

$\theta = 60°$

$\therefore 2\theta = 120°$

64. [1] For elastic collision $KE_i = KE_f$

$\Rightarrow \frac{1}{2}m\times 25 + \frac{1}{2}\times m\times 9 = \frac{1}{2}m\times 32 + \frac{1}{2}mv^2$

$\Rightarrow 34 = 32 + v^2$

$\Rightarrow v^2 = 2$

So, $KE_B = \frac{1}{2}\times 0.1\times 2 = 0.1\,J = \frac{1}{10}$

$\therefore x = 1$

65. (c) Using conservation of linear momentum

$m_1v_1\hat{i} + m_2v_2\hat{i} = m_1v_3\hat{i} + m_2v_4\hat{i}$

$\Rightarrow m_1v_1 + 0.5\,m_1v_2 = m_1(0.5\,v_1) + 0.5\,m_1v_4$

$v_1 + 0.5\,v_2 = 0.5\,v_1 + 0.5\,v_4$

$\therefore v_1 = v_4 - v_2$

66. (c) Applying conservation of linear momentum let v' be the final speed of the sytem,

$mv = (2m + M)v'$

$v' = \frac{mv}{2m+M}$

Initial kinetic energy $= \frac{1}{2}mv^2$

Final kinetic energy $= \frac{1}{2}(2m+M)\left(\frac{mv}{2m+M}\right)^2$

Initial kinetic energy − Final kinetic energy $= \frac{5}{6}$ of initial kinetic energy.

$\frac{1}{2}mv^2 - \frac{1}{2}(2m+M)\left(\frac{mv}{2m+M}\right)^2$

$= \frac{5}{6}\times\frac{1}{2}mv^2$

$\frac{1}{2}mv^2 - \frac{5}{12}mv^2$

$= \frac{1}{2}(2m+M)\frac{m^2v^2}{(2m+M)^2}$

$\frac{mv^2}{12} = \frac{m^2v^2}{2(2m+M)}$

$\Rightarrow 6m = 2m + M$

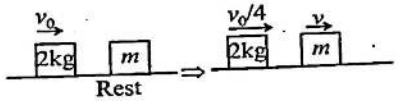
$\Rightarrow \frac{m}{M} = 4$

67. (b) Using conservation of linear momentum:

$2v_0 = 2\left(\frac{v_0}{4}\right) + mv$

$\Rightarrow 2v_0 = \frac{v_0}{2} + mv^2$

$\frac{3v_0}{2} = mv \Rightarrow m = \frac{3v_0}{2v}$



@FAKE_CBSE_X@RAJ_EDUNET

Since collision is elastic →

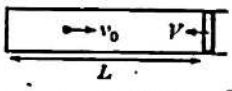
$V_{separation} = v_{approach}$

$v - \frac{v_0}{4} = v_0 \Rightarrow m = \frac{6}{5} = 1.2kg$

$v = \frac{5v_0}{4}$

$\therefore m = \frac{3v_0}{2\left(\frac{5v_0}{4}\right)} = \frac{6}{5} = 1.2kg$

68. (b,c)



Average rate of collision $= \frac{2L}{v}$

Speed of particle after collision $= 2V + v_0$

Change in speed after each collision $= (2V + v_0) - v_0 = 2V$

No. of collision per unit time (frequency) $= \frac{v}{2L}$

Change in speed in dt time $= 2V \times$ number of collision in dt time

$\Rightarrow dv = 2V\left(\frac{v}{2L}\right)\frac{dL}{V}$

$dv = \frac{vdL}{L}$

Now, $dv = -\frac{vdL}{L}$ (as L decrease)

$\int_{v_0}^{v} \frac{dv}{v} = -\int_{l_0}^{l_0/2} \frac{dL}{L}$

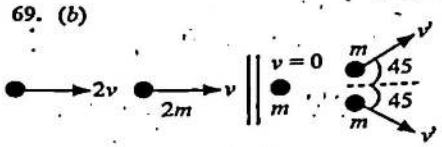
$\Rightarrow [\ln v]_{v_0}^{v} = -[\ln L]_{l_0}^{l_0/2}$

$\Rightarrow v = 2v_0 \Rightarrow KE_{l_0} = \frac{1}{2}mv_0^2$

and $KE_{l_0/2} = \frac{1}{2}m(2v_0)^2$

$\therefore \frac{KE_{l_0/2}}{KE_{l_0}} = 4$

69. (b)

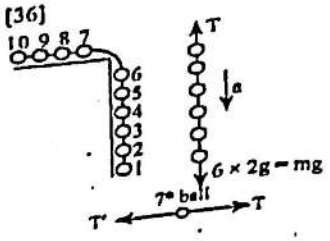


Using linear momentum conservation,

$m2v + 2mv = m \times 0 + m\frac{v'}{\sqrt{2}} \times 2$

$4mv = \frac{2mv'}{\sqrt{2}} \Rightarrow v' = 2\sqrt{2}v$

70. [36]



$12g - T = 12a$ ...(i)

$T - T' = 2a$ ...(ii)

$T' = 6a$ ...(iii)

From (i) & (ii)

$12g - 12a - T' 2a$ ...(iv)

From (iv) & (iii)

$12g - 12a - T' 14a$

$12g - T' = 14 \times \frac{T'}{6}$

$\Rightarrow 12g = T' + \frac{7}{3}T'$

$12g = \frac{10}{3}T' \Rightarrow T' = 36$

JEE-Advanced

1. (d) Given that the centre of mass is at a height h in each polygon. And polygons are neither slipping nor sliding.

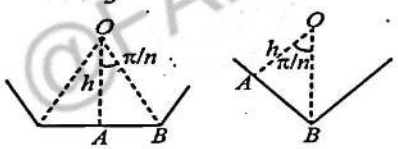
Therefore, $\tau_{net} = 0$

So all forces should pass through the point of contact.

For n_3, $\Delta h_3 = (2h - h) = h$

For n_4, $\Delta h_4 = (\sqrt{2}\,h - h) = (\sqrt{2} - 1)h$

For $n_5 = \frac{h}{5}$



$\cos\left(\frac{\pi}{n}\right) = \frac{h}{R}\Delta = R - h$

$= \frac{h}{\cos\left(\frac{\pi}{n}\right)} - h = h\left[\frac{1}{\cos\left(\frac{\pi}{n}\right) - 1}\right]$

2. (a) The y-coordinate of the centre of mass of the ink in this drawing is given by,

$Y_{CM} = \frac{6m \times 0 + ma + ma - ma + m \times 0}{6m + m + m + m + m}$

$Y_{CM} = \frac{ma}{10m} = \frac{a}{10}$

3. (d) $\vec{F}_{external} = Ma_{CM}$

Mutual force of attraction is an internal force i.e.

$\vec{F}_{external} = 0 \Rightarrow a_{CM} = 0 \Rightarrow V_{CM} = V_{CM}$

But initially, the system is at rest i.e.

$V_{CM} = 0 \Rightarrow V_{CM'} = 0$

Hence the speed of the centre of mass is zero at any instant.

4. (a,b) Using conservation of momentum

$mu = MV$ ...(i)

Using conservation of energy

$MgR = \frac{1}{2}mu^2 + \frac{1}{2}MV^2$ ...(ii)

Solving eqn. (i) and (ii) we get

$v = \sqrt{\frac{2gR}{1 + \frac{m}{M}}}$ and $V = \frac{m}{M}\sqrt{\frac{2gR}{1 + \frac{m}{M}}}$

The position of centre of mass as centre of mass of system is zero

$\therefore O = -m(R - x) + Mx \Rightarrow x = \frac{mR}{m + M}$

x-displacement of the centre of mass.

5. [False] Given $m_1 = 1$ kg, $m_2 = 3$ kg

$F_{ext} = 0$

When $\Delta v = 2$ m/sec, $v_{cm} = 0.5$ m/sec

When $\Delta v = 3$ m/sec, $v_{cm} = ?$

Since $F_{ext} = 0$

Acceleration(a) of COM $= 0$

v_{cm} = constant

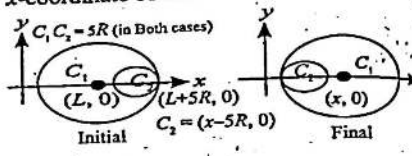
So, v_{com} does not depend upon relative velocity

So $\Delta v = 3$ m/sec, $v_{cm}' = 0.5$ m/sec.

So the given statement is false.

6. Since all the surfaces are smooth, no external force is acting on the system in horizontal direction. Therefore, the centre of mass of the system in horizontal direction remains stationary.

x-coordinate of CM initially will be given by



$x_I = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$

$= \frac{(4M)(L) + M(L+5R)}{4M + M} = (L + R)$

Let $(x, 0)$ be the coordinates of the centre of the large sphere in final position. Then x-coordinate of CM finally will be

$x_f = \frac{(4M)(x) + M(x-5R)}{4M + M} = (x - R)$

@FAKE_CBSE_@RAJ_EDUNET

Equating Eqs. (*i*) and (*ii*), we have
Therefore, coordinates of large sphere, when the smaller sphere reaches the other extreme position, are $(L + 2R, 0)$.

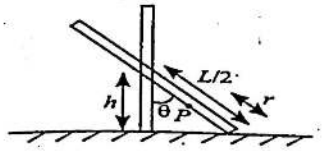
7. (*i*) Since, there is no horizontal force acting, the center of mass of the rod falls downwards.
i.e com moves on straight line path
(*ii*) From the diagram, x-coordinate of Point P is:

$$x = \frac{L}{2}\sin\theta - r\sin\theta$$

y-coordinate of point P is: $y = r\cos\theta$
Using $\sin^2\theta + \cos^2\theta = 1$

$$\frac{x^2}{\left(\frac{L}{2}-r\right)^2} + \frac{y^2}{r^2} = 1$$

The equation is that of an ellipse and hence, the shape of the path of this point is also an ellipse.
Because the equation is that of an ellipse, the form of this point's route is also an ellipse.



8. The diameter of both plates is 56 cm and 42 cm. So, their radius will be 28 cm and 21 cm respectively.
If the surface density is d, then
Mass of 28 cm radius plate $= d\pi(0.28)^2$ and
Mass of 21 cm radius plate $= d\pi(0.21)^2$
Calculate the center of mass after removing the plate
When smaller plate is removed and its center is at C, then for larger plate,

$$\text{Center of mass} = \frac{0 - 0.07 \times d\pi(0.21)^2}{d\pi[(0.28)^2 - (0.21)^2]}$$

$$X = \frac{-0.07}{(0.28)^2 - (0.21)^2} = -0.09\,\text{m} = -9\,\text{cm}$$

9. (*c*) Let v_1 and v_2 be the velocities after explosion in the directions shown in figure. From conservation of linear momentum, we have
$5(20\cos 60°) = 4v_1 - 1 \times v_2$, $4v_1 - v_2 = 50$ ...(*i*)
Just after explosion
Further, it is given that kinetic energy after an explosion becomes two times.
Therefore,

$$\frac{1}{2}\times 4\times v_1^2 + \frac{1}{2}\times 1\times v_2^2 = 2\left[\frac{1}{2}\times 5\times\left(20\cos 60°\right)^2\right]$$

or $4v_1^2 = v_2^2 = 1000$ ...(*ii*)
Just before explosion
when that, kinetic energy $v_1^2 + v_2^2 = 1000$
(*i*) and (*ii*), we have
Solving Eqs. (*i*) and (*ii*), we have $v_1 = 15$ m/s, $v_2 = 10$ m/s or $v_1 = 5$ m/s and $v_2 = -30$ m/s direction is 25 m/s.
$\therefore$ $x = 25t$ = distance between them when they strike the ground. Here,

$$t = \frac{T}{2}\ (T = \text{time of flight of projectile})$$

$$= \frac{u\sin\theta}{g} = \frac{20\sin 60°}{9.8} = 1.77\,\text{s}$$

$\therefore$ $x = 25 \times 1.77\,\text{m} = 44.25\,\text{m}$

10. (*a*) By the principal of conservation of momentum,

$$mv\cos\theta = -\frac{mV\cos\theta}{2} + \frac{m}{2}v'$$

i.e. $$\left(1+\frac{1}{2}\right)mv\cos\theta = \frac{m}{2}v'$$

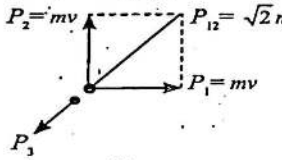
i.e. $v' = 3v\cos\theta$

11. (*a, d*) As given, $p_1 = p\hat{i}$ and $p_2 = -p\hat{i}$
Net Linear Momentum first before collision
$P_i = p_1 + p_2 = p\hat{i} - p\hat{i} = 0$
$\because$ No external force is acting on the balls, momentum will remain conserved.
$P_f = p_1 + p_2 = 0$
Option *a*,

$$p_f = \left(a_1\hat{i} + b_1\hat{j} + c_1\hat{k}\right) + \left(a_2\hat{i} + b_2 j\right)$$

$p_f = (a_1 + a_2)i + (b_1 + b_2)j + c_1\,\hat{k} \neq 0$
(because $c_1 \neq 0$)
And, Option *d*, $p_f = \left(a_1\hat{i} + b_1 j\right) + \left(a_2\hat{i} + b_1 j\right)$.
$p_f = (a_1 + a_2)i + (2b_1)j \neq 0$ (because $b_1 \neq 0$)

12. From conservation of linear momentum p_3 should be $\sqrt{2}mv$ in a direction opposite to p_{12} (resultant of p_1 and p_2). Let v' be the speed of third fragment, then
(2 m) $v' = \sqrt{2}mv$



$$\therefore\quad v' = \frac{v}{\sqrt{2}}$$

$\therefore$ Total energy released is,

$$E = 2\left(\frac{1}{2}mv^2\right) + \frac{1}{2}(2m)v'^2$$

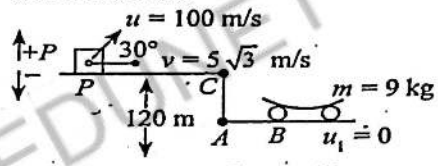
$$= mv^2 + m\left(\frac{v}{\sqrt{2}}\right)^2 = \frac{3}{2}mv^2$$

13. [False] Since, net force on the system is zero. Velocity of centre of mass will remain constant.

14. Speed of car $v = 5\sqrt{3}$ m/s
Mass of carriage $M = 9$ kg
Mass of each cannonball = 1 kg
Consider the vertical motion of the cannon ball,

$$S = ut + \frac{1}{2}at^2$$

$-120 = 50t_0 - 5t_0^2$
$\Rightarrow\ 5t_0^2 - 50t_0 - 120 = 0$
$\Rightarrow\ t_0^2 - 10t_0 - 24 = 0$
Thus $t_0 = 12$ or -2
The horizontal velocity of the cannon ball remains the same.



$v = 100\cos 30° + 5\sqrt{3} = 55\sqrt{3}$ m/s
Apply conservation of linear momentum to the cannonball-trolley system in horizontal direction. If m is the mass of cannonball and M is the mass of the trolley then,
$m \times v_x + M \times 0 = (m + M)\,V_x$

$$V_x = \frac{mv_x}{(m+M)}$$

where v_x is the velocity of the (cannonball - trolley) system.

$$V_x = \frac{1\times 55\sqrt{3}}{-1+9} = 5.5\sqrt{3}\ \text{m/s}$$

The second ball was projected after 12 second
Horizontal distance covered by the car,
$P = 12 \times 5\sqrt{3} = 60\sqrt{3}$ m.
Since the second ball also struck the trolley.
$\Rightarrow$ In time 12 seconds the trolley covers a distance of $60\sqrt{3}$
For trolley in 12 sec,

$$\text{From s} = \left(\frac{u+v}{2}\right) + 60\sqrt{3}$$

$$= \left(\frac{5.5\sqrt{3}+v}{2}\right) \times 12$$

$v = 7.8$ m/s
To find the final velocity of the carriage after the second impact we again apply conservation of linear momentum in the horizontal direction.
$mv_x + (m + M)\,7.8 = (M + 2m)v_f$
$1 \times 55\sqrt{3} + (9 + 1)\,7.8 = (9 + 2)\,v_f$
$v_f = 15.75$ m/s

@IIT-JEE-CBSE-NCERT-MEDICAL-NET

15.

IMAGE-1 IMAGE-2 IMAGE-3

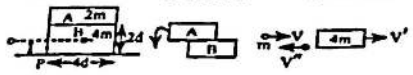
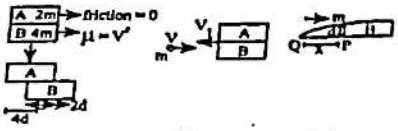


IMAGE-4 IMAGE-5 IMAGE-6



The block B should at least move $2d$.

Ref. image 2

So, there is a chance for A to get topple.

a. $\Sigma F_x = 0$ (momentum conserve)

Ref. image 3

$mv = 4mv' + mv''$

$v'' = v - 4v'$

From law of conservation of energy,

$\frac{1}{2}mv^2 = \frac{1}{2}(4m)v'^2 + \frac{1}{2}mv''^2$

$v^2 = 4v'^2 + v''^2$

$v' = \frac{2v}{5}$ (after collision)

Ref. image 4

$v' = \frac{2v}{5}, v = 0, s = 2d$

$F = \mu N = (4m)\, a = \mu\,(6m)g$

$a = -1.5\ \mu g$

$v^2 - u^2 = 2as$

$v = \frac{5}{2}\sqrt{6\mu gd}$

b. From law of conservation of momentum,

$v_1 = \frac{(m_1 - m_2)u_1}{(m_1 + m_2)} + \frac{2m_2u_2}{(m_1 + m_2)}$

$m_1 = m, m_2 = 4m$

$u_1 = 2v_0 = 2v$

$u_1 = 2 \times \frac{5}{2}\sqrt{6\mu gd}$

$v_1 = \frac{(m-4m)5\sqrt{6\mu gd}}{m+4m} + \frac{2 \times 4m(0)}{(m+4m)}$

$\frac{-3m5\sqrt{6\mu gd}}{5m}$

$v_1 = -3\sqrt{6\mu gd}$

Ref. image 6

Consider vertical motion,

$u_y = 0, s_y = d, t_y = ?$

$s_y = u_y t + \frac{1}{2}a_y t^2$

$d = \frac{1}{2}a_y t^2$

$t = \sqrt{\frac{2d}{g}}$

$v_x = 3\sqrt{6\mu gd}$

$X = v_x \times t = 6d\sqrt{3\mu}$

16.

Given that: Collision.

(*i*) Now, Applying momentum conservation,

$\Rightarrow mv_0 = mv + 2mv \Rightarrow v_0 = 3v$

$\Rightarrow v = \frac{v_0}{3}\ m/s$

Hence, common velocity of Block A and B is $\frac{V_0}{3}\ m/s$

(*ii*) Now, applying Mechanical energy Conservation:-

Potential energy in spring = Change in Kinetic energy

$\frac{1}{2}mv_0^2 = \frac{1}{2}m\left(\frac{v_g}{3}\right)^2 + \frac{1}{2}(2m)\left(\frac{v_g}{3}\right)^2 + \frac{1}{2}kx_0^2$

$= \frac{1mv_0^2}{29} + \frac{1}{2}2m\frac{v_0^2}{9} + \frac{1}{2}kx_0^2$

$\Rightarrow mv_0^2 = \frac{mv_0^2}{3} + kx_0^2$

$\therefore kx_0^2 = \frac{2}{3}mv_0^2 \therefore k = \frac{2mv_0^2}{3x_0^2}$

17. (*a*) The centre of mass of $M + m$ in this case it will not move in a horizontal direction. Let M moves towards left by a distance x then m will move towards right by a distance $R - r - x$ (with respect to ground). For centre of mass not to move along horizontal we should have

$Mx = m(R - r - x), x = \frac{m(R-r)}{M+m}$

(*b*) Let v_1 be the speed of m towards right and v_2 the speed of M towards the left. From conservation of linear momentum.

$mv_1 = Mv_2$ ...(*i*)

From of conservation of mechanical energy

$mg(R - r) = \frac{1}{2}mv_1^2 + \frac{1}{2}Mv_2^2$

Solving these two equations, we get

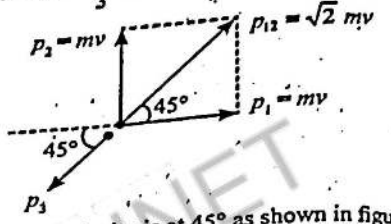
$v_2 = m\sqrt{\frac{2g(R-r)}{M(M+m)}}$

18. From conservation of linear momentum p_3 should be equal and opposite to p_{12} (resultant of p_1 and p_2). So, let v' be the velocity of third fragment, then

$(3m)v' = \sqrt{2}mv \Rightarrow \therefore v' = \frac{\sqrt{2}}{3}v$

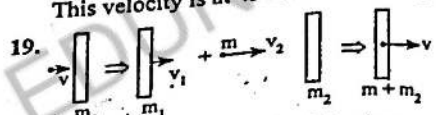
Here, $v = 30$ m/s (given)

$\Rightarrow v' = \frac{\sqrt{2}}{3} \times 30 = 10\sqrt{2}$ m/s



This velocity is at 45° as shown in figure.

19.



Let initial velocity bullet 'u' m/sec.

$M = 20\ g = 0.02\ kg$

Velocity of each plate

$v_1 = v_2 = v$

Applying conservation of momentum,

$mu = M_1v_1 + [M_2 + m]\, v_2$

$0.02u = 1v + [2.98 + 0.02]v_2$

$0.02u = v + 3v$

$0.02u = 4v$

$u = 200v$

Let u_1 is the velocity of the bullet when it comes out of the first plate.

$mu_1 = mv_2 + M_2v_2$

$mu_1 = (m + M_2)\, v_2 = (m + M_2)v$

$0.02u_1 = [0.02 + 2.98]v$

$u_1 = \frac{3}{0.02}v$

$u_1 = 150v$

Percentage loss in initial velocity of bullet when it is moving between M_1 & M_2,

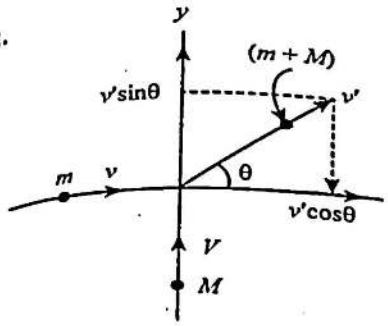
$\frac{u - u_1}{u} \times 100 = \frac{200 - 150}{200} \times 100$

$= \frac{50}{200} \times 100 = 25\%$

20. No, the situation given does not violate conservation of linear momentum. Because the linear momentum of the ball-earth system remains constant.

@FAKE_CBSE_X@RAU_EDUNET

21.



Applying conservation of momentum along X-axis,

$mV = (m+M)V'\cos\theta$ ...(i)

Along Y-axis,

$mv = (m+M)V'\sin\theta$ ...(ii)

From (i) & (ii) we get,

$V' = \dfrac{mv}{(m+M)\cos\theta}$ and V'

$= \dfrac{mV}{(m+M)\sin\theta}$

Equating (i) & (ii)

$\dfrac{mv}{(m+M)\cos\theta} = \dfrac{mV}{(m+M)\sin\theta}$

$\tan\theta = \dfrac{mV}{mV} \Rightarrow \theta = \tan^{-1}\left(\dfrac{mV}{mV}\right)$

Squaring and adding equation (i) & (ii) we get,

$(m+M)^2V'^2\cos^2\theta + (m+M)^2V'^2\sin^2\theta$

$V' = \dfrac{\sqrt{m^2V^2 + M^2v^2}}{(M+m)}$

$KE_i = \dfrac{1}{2}mv^2 + \dfrac{1}{2}mv^2$

$K.E_f = \dfrac{1}{2}(M+m)V'$

$= \dfrac{1}{2}(M+m)\left[\dfrac{m^2V^2 + M^2v^2}{(m+M)^2}\right]$

The fraction of the initial K.E transformed into heat during the collision,

$= \dfrac{K_f - K_i}{K_i}$

$= \dfrac{\frac{1}{2}\left(\frac{m^2v^2 + m^2V^2}{(m+m)}\right) - \left(\frac{1}{2}mv^2 + \frac{1}{2}mV^2\right)}{\left(\frac{1}{2}mv^2 + \frac{1}{2}mv^2\right)}$

$= \dfrac{Mm(v^2 + V^2)}{(M+m)(mv^2 + mV^2)}$

22. (d) $v = v_0 e^{\frac{-t}{\tau}}$

$\Rightarrow v_0 = \dfrac{J}{m} = 2.5$ m/s

$v = v_0 e^{\frac{-t}{\tau}}$

$\dfrac{dx}{dt} = v_0 e^{\frac{-t}{\tau}}$

$\int_0^x dx = v_0 \int_0^t e^{\frac{-t}{\tau}} dt$

$\int e^{-x} dx = \dfrac{e^{-x}}{-1}$

$X = v_0\left[\dfrac{e^{\frac{-t}{\tau}}}{\frac{1}{\tau}}\right]$

(Because $\tau = 4$s and $t = \tau$)

$X = 2.5(-4)(e^{-1} - e^0)$

$X = 2.5(-4)(0.37 - 1)$

$x = 6.30 \approx 6$

23. (c) The velocity of the heavier block (10 kg) = 14 m/s.

The velocity of COM is given by:

$\dfrac{m_1v_1 + m_2v_2}{m_1 + m_2}$

$= \dfrac{10\times14 + 4\times0}{10+4} = 10\,\text{m/s}$

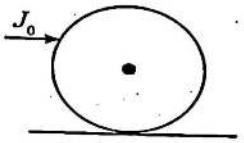
Since spring force is an internal force.

24. (a, b, c, d) We know that,

$J_0 = mv$ ...(i)

$J_0h_m = I_c\omega$ ...(ii)

$v = \omega R$ ...(iii)



$\Rightarrow h_m = \dfrac{I_c\omega}{J_0} = \dfrac{I_c\omega}{mv} = \dfrac{I_c\omega}{m\omega R} = \dfrac{I_c}{mR}$

From the options

(a) If $a = 0$, $I_c = \dfrac{1}{2}mb^2$ & $R = b$

$\therefore h_m = \dfrac{b}{2}$

(b) If $a = b$, $I_c = mb^2$ & $R = b$

$\therefore h_m = b$

(c) $v = \dfrac{J_0}{m} \Rightarrow 100 = \dfrac{V}{R} = \dfrac{J_0}{mR}$

(d) Force is acting on center of mass

$\therefore$ No rotation.

25. [0.005] $dP = Fdt$

Integrating both sides we get $\int dP = \int Fdt$

So, the impulse dP is nothing but area under $F - t$ graph.

Area $= \dfrac{1}{2}$(sum) × separation + $\dfrac{1}{2}$ base × height

or

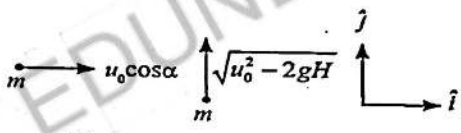
$dP = \dfrac{1}{2}(200 + 800)N + (6 - 4)\,\mu\text{sec}$

$+ \dfrac{1}{2} \times (16 - 6)\mu \times 800N = 5000\ N\,\mu\text{sec}$

$= 0.005\ N$ sec

26. (a) From momentum conservation equation, we have, $P_i = P_f$

Also, we know that, in perfectly inelastic collision particle stick together. After collision.



Hence,

$p_i = p_f = m(u_0\cos\alpha)\hat{i} + m\left(\sqrt{u_0^2 - 2gH}\right)\hat{j}$

$= (2m)v$; Put $H = \dfrac{u_0^2\sin^2\alpha}{2g}$

$v = \dfrac{u_0\cos\alpha}{2}\hat{i} + \dfrac{u_0\cos\alpha}{2}\hat{j}$

Since both components of v are equal. Therefore, it is making 45° with horizontal.

27. (d) Let the mass of bullet be m and mass of ball be M initially ball is at height 5 m and t rest, the only acceleration is due to gravity therefore applying equation of motion

$S = ut + \dfrac{1}{2}gt^2$

$5 = 0 + \dfrac{1}{2}(10)t^2$

Therefore $t = 1$ sec } After collision

So, V (ball) = 20 m/s

V (bullet) = 100 m/s

So by collision

$M \times V$ (ball : final) + $m \times V$ (bullet: final) = $M \times V$ (ball : initial) + $m \times V$ (bullet initial)

$0.01 \times V$ (bullet initial) = $0.01 \times 100 + 0.20 \times 20$

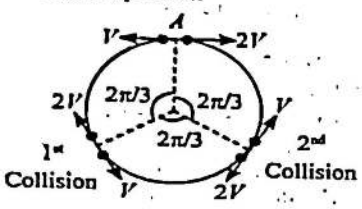
$\Rightarrow$ Bullet Initial Velocity = V = 500 m/s

@FAKE_CBSE_A @RAJ_EDUNET

28. (c) At first collision one particle having speed

$2v$ will rotate $240^\circ \left(\text{or } \frac{4\pi}{3}\right)$ while other particle having

speed v will rotate $120^\circ \left(\text{or } \frac{2\pi}{3}\right)$. At first collision, they will exchange their velocities. Now, as shown in figure, after two collisions they will again reach at point A.



29. (b) In case of elastic collision, coefficient of restitution $e = 1$.

Magnitude of relative velocity of approach = Magnitude of relative velocity of separation.

But relative speed of approach ≠ Relative speed of separation.

Momentum will conserve in all type of collision.

30. (c) After collision they become a system of mass $(m_1 + m_2)$.

Now, the gravitational force will only act on them. The force $= (m_1 + m_2)g$

According to Newton's law of motion,

$F = \left|\frac{\Delta p}{\Delta t}\right|$ where Δp = change in

Now, the change in momentum (magnitude)

$$\Rightarrow \left|m_1\vec{v}_1 + m_2\vec{v}_2 - (m_1\vec{u}_1 + m_2\vec{u}_2)\right|$$

$$\Rightarrow \frac{\left|m_1\vec{v}_1 + m_2\vec{v}_2 - (m_1\vec{u}_1 + m_2\vec{u}_2)\right|}{2t_0 - 0}$$

$$= (m_1 + m_2)g$$

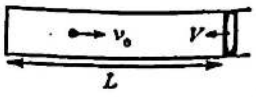
$$\Rightarrow \left|m_1\vec{v}_1 + m_2\vec{v}_2 - (m_1\vec{u}_1 + m_2\vec{u}_2)\right|$$

$$= 2(m_1 + m_2)gt_0$$

31. (c) Since we know that - During the collision an impulsive force is generated which is an internal force for the system.

So, we can conserve the total momentum of the ball and the earth.

32. (b, c)



Average rate of collision $= \frac{2L}{v}$

Speed of particle after collision $= 2V + v_0$

Change in speed after each collision $= (2V + v_0) - v_0 = 2V$

No. of collision per unit time (frequency) $= \frac{v}{2L}$

Change in speed in dt time $= 2V \times$ number of collision in dt time

$$\Rightarrow dv = 2V\left(\frac{v}{2L}\right)\cdot\frac{dL}{V}$$

$$dv = \frac{v\,dL}{L}$$

Now, $dv = -\frac{v\,dL}{L}$ {as L decrease}

$$\int_{v_0}^{v}\frac{dv}{v} = -\int_{L_0}^{L_0/2}\frac{dL}{L}$$

$$\Rightarrow [\ln v]_{v_0}^{v} = -[\ln L]_{L_0}^{L_0/2}$$

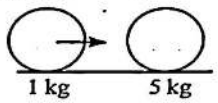
$$\Rightarrow v = 2v_0$$

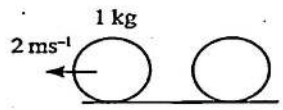
$$\Rightarrow KE_{L_0} = \frac{1}{2}mv_0^2 \text{ and}$$

$$KE_{L_0/2} = \frac{1}{2}m(2v_0)^2$$

$$\therefore \frac{KE_{L_0/2}}{KE_{L_0}} = 4$$

33. (a, c) We know, formula for final velocity after collision,





$$\Rightarrow v_1' = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)v_1 + \left(\frac{2m_2}{m_1 + m_2}\right)v_2$$

$$-2 = \left(\frac{1-5}{1+5}\right)v_1 + 0(\text{as } v_2 = 0)$$

$$v_1 = 3 \text{ ms}^{-1}$$

$$v_2' = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)v_2 + \left(\frac{2m_1}{m_1 + m_2}\right)$$

$$v_1 = 1 \text{ ms}^{-1}$$

Initial momentum

$P_{CM} = P_i = (1)(3) = 3$ kg m/s

Momentum of 5 kg block after collision is

$P_3' = (5)(1) = 5$ kg − m/s

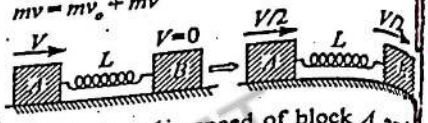
$$K_{CM} = \frac{P_{CM}^2}{2M_{CM}} = \frac{9}{2\times 6} = 0.75 \text{ J}$$

K.E of system,

$$K_{total} = \frac{1}{2}\times 1\times (3)^2 = 4.5 \text{ J}$$

34. (b, d) AB and C are identical after collision of C with A linear momentum conservation

$mv = mv_0 + mv$



$v' = v$ v' = speed of block A and get rest.

At time of maximum compression both A and B moves with constant velocity

$mv = (m + m)v'$

$$v' = \frac{v}{2}$$

K.E of both block A and B is

$$= \frac{1}{2}2m\left(\frac{v}{2}\right)^2$$

$$= \frac{mv^2}{4}$$

According energy conservation

$$\frac{1}{2}mv^2 = K\cdot E + P\cdot E$$

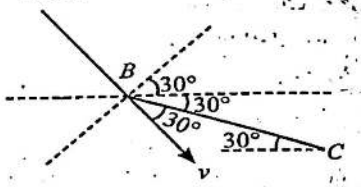
$$\frac{1}{2}mv^2 = \frac{mv^2}{4} + \frac{k}{2}x^2$$

$$\frac{mv^2}{2} = kx^2$$

$$x = v\sqrt{\frac{m}{2k}},$$

x = maximum compression

35. (b) Between A and, B height fallen by block



$h_1 = \sqrt{3}\tan 60^\circ = 3$ m

∴ Speed of block just before striking the second incline,

$v_1 = \sqrt{2gh_1} = \sqrt{2\times 10\times 3} = \sqrt{60}$ ms^{-1}

@RAKE_CBSE_X_@RAJEEDNET

In perfectly inelastic collision, component of v_1 perpendicular to BC will become zero, while component of v_1 parallel to BC will remain unchanged.

Speed of block B immediately after it strikes the second incline is,

v_2 = component of v_1 along BC

$= v_1\cos 30^\circ = \left(\sqrt{60}\right)\left(\frac{\sqrt{3}}{2}\right)$

$= \sqrt{45}\ \text{ms}^{-1}$

36. (*b*) Height fallen by the block from B to C

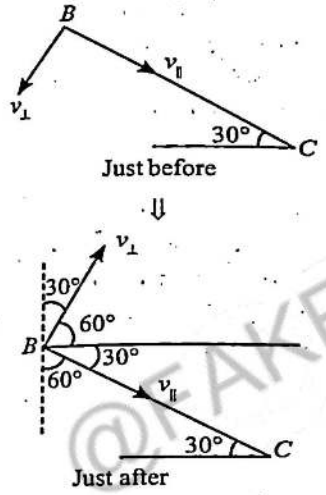
$h_2 = 3\sqrt{3}\tan 30^\circ = 3$ m

Let v_3 be the speed of block, at point C, just before it leaves the second incline, then

$v_3 = \sqrt{v_2^2 + 2gh_2} = \sqrt{45 + 2\times 10\times 3}$

$= \sqrt{105}\ \text{ms}^{-1}$

37. (*c*) In elastic collision, compound of v_1 parallel to BC will remain unchanged, while component perpendicular to BC will remain unchanged in magnitude but its direction will change.



$v_\parallel = v_1\cos 30^\circ$

$= \left(\sqrt{60}\right)\left(\frac{\sqrt{3}}{2}\right) = \sqrt{45}\ \text{ms}^{-1}$

$v_\perp = v_1\sin 30^\circ = \left(\sqrt{60}\right)\left(\frac{1}{2}\right) = \sqrt{15}\ \text{ms}^{-1}$

Now vertical component of velocity of block

$v = v_\perp\cos 30^\circ - v_\parallel\cos 60^\circ$

$= \left(\sqrt{15}\right)\left(\frac{\sqrt{3}}{2}\right) - \left(\sqrt{45}\right)\left(\frac{1}{2}\right) = 0$

38. [30]

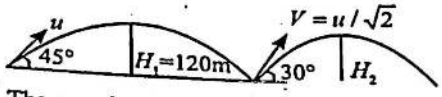
$H_1 = \frac{u^2\sin^2 45}{2g} = 120,\ \frac{u^2}{4g} = 120$ ...(*i*)

When half of kinetic energy is lost $v = \frac{u}{\sqrt{2}}$

$H_2 = \frac{\left(\frac{u}{\sqrt{2}}\right)^2\sin^2 30}{2g} = \frac{u^2}{16g}$ ...(*ii*)

From (*i*) and (*ii*)

$H_2 = \frac{H_1}{4} = 30$ m



39. The question is to be solved by balancing the torque. Torque is because of gravity and impulse imparted by the balls. Impulsive force by the balls can be considered to be acting at the center of the shaded region and mag is acting at the center of the plate.

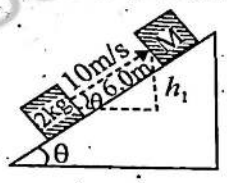
$\frac{Mgb}{2} = n(2\,mv)\left(\frac{3b}{4}\right)\times a\times\frac{b}{2}$

$\Rightarrow v = \frac{3\times 10\times 2\times 1}{6\times 100\times 0.01} = 10\text{m/s}$

40. Let v_1 velocity of block 2 kg just before collision, v_2 = velocity of block 2 kg just after collision, and v_3 = velocity of block M just after the collision.

Applying work-energy theorem (change in kinetic energy - work done by all the forces) at different stages as shown in figure.

(1) During up the plane.



$h_1 = 6\sin\theta$
$= 0.3$ m

Figure 1. $\Delta KE = W_{friction} + W_{gravity}$

$\left[\frac{1}{2}m\left\{v_1^2 - (10)^2\right\}\right] = -6\mu mg\cos\theta - mgh_1$

or $v_1^2 - 100 = -2[6\mu\cos\theta + gh_1]$

$\cos\theta = \sqrt{1-\sin^2\theta} = \sqrt{1-(0.05)^2} \approx 0.99$

$\therefore v_1^2 = 100 - 2[(6)(0.25)(10)(0.99) + (10)(0.3)]$

$\Rightarrow v_1 \approx 8$ m/s

(2) During down the plane.

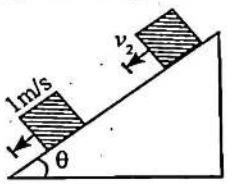


Figure 2. $\Delta KE = W_{friction} + W_{gravity}$

$\frac{1}{2}m\left[(1)^2 - \left(v_2^2\right)\right] = -6\mu mcos0 + mgh_1$

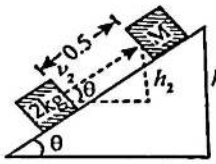
or $1 - v_1^2 = 2[-6\mu mcos0 + gh_1]$

$= 2[-(6)(0.25)(10)(0.99) + (10)(0.3)]$

$= 23.7\ v_2^2 = 27.7\ v_2 \approx 5$ m/s

or Figure 3. $\Delta KE = W_{friction} + W_{gravity}$

$\frac{1}{2}M\left[0 - v_3^2\right] = -(0.5)(\mu)(M)g\cos\theta - mgh_2$



$h_2 = 0.5\sin\theta$
$= 0.025$ m

or $-v_3^2 = -\mu g\cos\theta - 2gh_2$

or $-v_3^2 = (0.25)(10)(0.99) + 2(10)(0.025)$

or $-v_3^2 = 2.975 \Rightarrow v_3 \approx 1.72$ m/s

Now,

(*a*) Coefficient of restitution

$= \frac{\text{Relative velocity of separation}}{\text{Relative velocity of approach}}$

$= \frac{v_2 + v_3}{v_1} = \frac{5 + 1.72}{8} = \frac{6.72}{8}$ or $e \approx 0.84$

(*b*) Applying conservation of linear momentum before and after collision

$2v_1 = Mv_3 - 2v_2 \therefore M = \frac{2(v_1 + v_2)}{v_3}$

$= \frac{2(8+5)}{1.72} = \frac{26}{1.72},\ M = 15.12\,kg.$

41. Given that,

solid of mass $= 10^{-2}$ kg,

cross-sectional area $= 10^{-4}$ m^2

speed $= 10^3$ m/s

dust particles density $= 10^{-3}$ kg/m^3

Using conservation of momentum,

$mu = (m + M)v$

$\Rightarrow v = \frac{mu}{(m + \rho Ax)}$

$\Rightarrow \frac{dx}{dt} = \frac{mu}{(m + \rho Ax)}$

$\Rightarrow \int_0^{150}(m + \rho Ax)\,dx = \int_0^t mu\,dt$

$\left(mx + \rho A\frac{x^2}{2}\right) = mut$

$10^{-2}\times x + 10^{-3}\times\frac{10^{-4}}{2}x^2 = 10^{-2}\times 10^3\times 150,$

By solving eqn, we get $x = 10^5$

Thus, the answer is 10^5.

42. (*a*) Let $\hat{i}, \hat{j}$ and $\hat{k}$ be the unit vectors along x, y and z-directions respectively.

@TAKE_CBSE_V@RAJ_EDUNET

Given, $v_s = 4\hat{i}$ m/s

$= \left(4\hat{i} + 3\hat{j} + 3\sqrt{3}\hat{k}\right)$ m/s

This is the absolute velocity of stone (with respect to ground). At highest point of its trajectory, the vertical component (z) of its velocity will become zero, whereas the x and y-components will remain unchanged. Therefore, velocity of stone at highest point will be,

$v = \left(4\hat{i} + 3\hat{j}\right)$ m/s

or speed at highest point,

$v = |v| = \left(\sqrt{(4)^2 + (3)^2}\right)$ m/s $= 5$ m/s

Now, applying law of conservation of linear momentum, Let v_0 be the velocity of combined mass after collision.

Then,

$\therefore v_0 = \frac{v}{2} = \frac{5}{2}$ m/s $= 2.5$ m/s

∴ Speed of combined mas just after collision is 2.5 m/s.

(*b*) Tension in the string becomes zero at horizontal position. It implies that velocity of combined mass also becomes zero in horizontal position. Applying conservation of energy, we have

$\therefore L = \frac{v_0^2}{2g} = \frac{(2.5)^2}{2(9.8)} = 0.32$ m

Hence, length of the string is 0.32 m.

43. The pendulum bob is left from the position *A*. When it is at position *C*, the angular position amplitude is 60°.

In ΔOCM as shown in above figure,

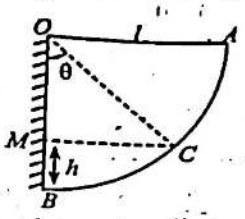
$\cos 60° = \frac{OM}{l} \Rightarrow OM = \frac{l}{2}$

The velocity of the bob at *B*, V_B Before first collision is

$mgl = \frac{1}{2}mV_B^2 \Rightarrow V_B = \sqrt{2gl}$

Let after n collisions, the angular amplitude is 60° when the bob again moves towards the wall from *C*, the velocity V_B before collision is

$mg\frac{l}{2} = \frac{1}{2}mV_B^2 \Rightarrow V_B = \sqrt{gl}$



This means that the velocity of the bob should reduce from $\sqrt{2gl}$ to $\sqrt{gl}$ due to collisions with walls.

The final velocity after n collisions is $\sqrt{gl}$.

Therefore, $e^n\sqrt{2gl} = \sqrt{gl}$

where e is the coefficient of restitution.

$\left(\frac{2}{\sqrt{5}}\right)^n \times \sqrt{2gl} = \sqrt{gl} \Rightarrow \left(\frac{2}{\sqrt{5}}\right)^n = \frac{1}{\sqrt{2}}$

Taking log on both sides we get,

$n \log\left(\frac{2}{\sqrt{5}}\right) = \log\frac{1}{\sqrt{2}}$

$n = 3.1$

Thus the minimum number of collisions after which the amplitude becomes less than 60° is 4

44. Suppose they meet after time t_0 then sum of magnitudes of their displacement should be $H = 98$ m

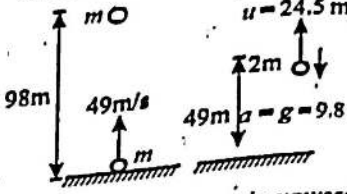
or $h_1 + h_2 = \left(49t_0 - \frac{9.8}{2}t_0^2\right) + \frac{9.8}{2}t_0^2 = 98$

so $t_0 = 2$ sec

Now we know that after 2 sec the velocity of first particle in upward direction will be

$v_1 = 49 - 9.8 \times 2 = 29.4$ m/s

and the velocity of second particle a
these 2 sec will be $v_2 = 9.8 \times 2 = 19.6$
in downward direction.



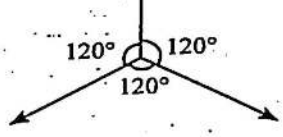
so the net momentum in upward direct
will be $p = m \times 29.4 - m \times 19.6 = 9.$
so net upward velocity of his combi
mass($2m$) will be $V = \frac{p}{2m} = 4.9$ m/s
this height from ground will be $h_1 = 49$
$2 - 4.9 \times 4 = 78.4m$ now using follow
equation $h = -Vt + 4.9t^2$ putting $h = 78.4$
and $V = 4.9$ m/s we get $t = 4.5$ sec

So, time of flight will be $t + t_0 = 6.5$ sec

45. The velocities of three particles are direc
as shown in figure.

It is clear that the three velocity vectors a
inclined at an angle of 120°.

We know that the resultant of three equ
vectors inclined at an angle of 120° is zer
So, the resultant initial momentum of th
system is zero. It means that the resulta
final momentum of the system must be zer
As particle *A* comes at rest after collisio
the momentum of particle *C* must be equa
and opposite to the momentum of partic
B, for the final momentum to be zero. Thu
the velocity of *C* should be equal to v an
directed opposite to that of *B*.



@AKL_CBSE_KY @RLJ_EDUNET

8 Rotational Motion

Scan for ⊙ Sol.

JEE-Main

Angular Displacement, Velocity and Acceleration

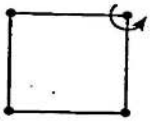
1. The angular speed of truck wheel is increased from 900 rpm to 2460 rpm in 26 seconds. The number of revolutions by the truck engine during this time is _____ (Assuming the acceleration to be uniform). **[17 March, 2021 (Shift-I)]**

2. A clock has a continuously moving second's hand of 0.1 m length. The average acceleration of the tip of the hand (in units of ms^{-2}) is of the order of **[6 Sep, 2020 (Shift-I)]**
   (a) 10^{-1} (b) 10^{-2} (c) 10^{-4} (d) 10^{-3}

3. A bead of mass m stays at point $P(a, b)$ on a wire bent in the shape of a parabola $y = 4Cx^2$ and rotating with angular speed ω (see figure). The value of ω is (neglect friction) **[2 Sep, 2020 (Shift-I)]**
   (a) $2\sqrt{2gC}$ (b) $2\sqrt{gC}$ (c) $\sqrt{\frac{2g}{C}}$ (d) $\sqrt{\frac{2gC}{ab}}$

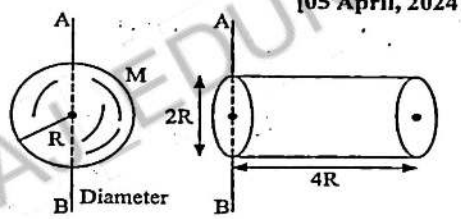
Moment of Inertia, Radius of Gyration

4. Four particles each of mass 1 kg are placed at four corners of a square of side 2 m. Moment of inertia of system about an axis perpendicular to its plane and passing through one of its vertex is _____ kgm^2. **[27 Jan, 2024 (Shift-I)]**



5. Two identical spheres each of mass 2 kg and radius 50 cm are fixed at the ends of a light rod so that the separation between the centers is 150 cm. Then, moment of inertia of the system about an axis perpendicular to the rod and passing through its middle point is $\frac{x}{20}\,kg\,m^2$, where the value of x is **[31 Jan, 2024 (Shift-II)]**

6. Ratio of radius of gyration of a hollow sphere to that of a solid cylinder of equal mass, for moment of Inertia about their diameter axis AB as shown in figure is $\sqrt{\frac{8}{x}}$. The value of x is: **[05 April, 2024 (Shift-I)]**



(a) 34 (b) 17 (c) 67 (d) 51

7. Three balls of masses 2 kg, 4 kg and 6 kg respectively are arranged at centre of the edges of an equilateral triangle of side 2 m. The moment of inertia of the system about an axis through the centroid and perpendicular to the plane of triangle, will be _____ kg m^2. **[06 April, 2024 (Shift-II)]**

8. A uniform solid cylinder with radius R and length L has moment of inertia I_1, about the axis of cylinder. A concentric solid cylinder of radius $R' = \frac{R}{2}$ and length $L' = \frac{L}{2}$ is carved out of the original cylinder. If I_2 is the moment of inertia of the carved out portion of the cylinder then $\frac{I_1}{I_2} =$
   (Both I_1 and I_2 are about the axis of the cylinder) **[24 Jan, 2023 (Shift-II)]**

9. Moment of inertia of a disc of mass M and radius 'R' about any of its diameter is $\frac{MR^2}{4}$. The moment of inertia of this disc about an axis normal to the disc and passing through a point on its edge will be, $\frac{x}{2}MR^2$. The value of x is _____. **[1 Feb, 2023 (Shift-II)]**

10. A ring and a solid sphere rotating about an axis passing through their centers have same radii of gyration. The axis of rotation is perpendicular to plane of ring. The ratio of radius of ring to that of sphere is $\sqrt{\frac{2}{x}}$. The value of x is **[6 April, 2023 (Shift-2)]**

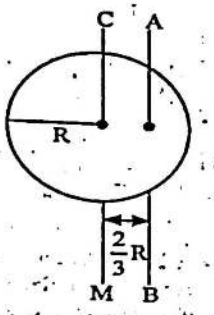
PEACE_CBSE_X @RACE DUNET

11. The moment of inertia of semicircular ring about an axis, passing through the center and perpendicular to the plane of ring, is $\frac{1}{x}MR^2$, where R is the radius and M is the mass of semicircular ring. The value of x will be [8 April, 2023 (Shift-I)]

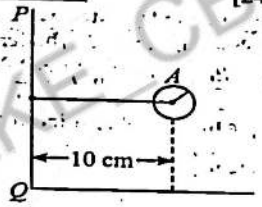
12. Two discs of same mass and different radii are made of different materials such that their thicknesses are 1 cm and 0.5 cm respectively. The densities of materials are in the ratio 3:5. The moment of inertia of these discs respectively about their diameters will be in the ratio of $\frac{x}{6}$. The value of x is [31 Jan, 2023 (Shift-II)]

13. A solid sphere and a solid cylinder of same mass and radius are rolling on a horizontal surface without slipping The ratio of their radius of gyrations respectively (K_{sph} : K_{cyl}) is $2:\sqrt{x}$, then value of x is_____. [15 April, 2023 (Shift-I)]

14. I_{CM} is the moment of inertia of a circular disc about an axis (CM) passing through its center and perpendicular to the plane of the disc. I_{AB} is it's moment of inertia about an axis AB perpendicular to plane and parallel to the axis CM at a distance $\frac{2}{3}R$ from the center. Where R is the radius of the disc. The ratio of I_{AB} and I_{CM} is $x:9$. The value of x is _____ [25 Jan, 2023 (Shift-I)]



15. Solid sphere A is rotating about an axis PQ. If the radius of the sphere is 5 cm then its radius of gyration about PQ will be $\sqrt{x}$ cm. The value of x is _____. [24 Jan, 2023 (Shift-I)]



16. Two identical solid spheres each of mass 2 kg and radii 10 cm are fixed at the ends of a light rod. The separation between the centres of the spheres is 40 cm. The moment of inertia of the system about an axis perpendicular to the rod passing through its middle point is _____ $\times 10^{-3}$ $kg\text{-}m^2$ [6 April, 2023 (Shift-I)]

17. If a solid sphere of mass 5kg and a disc of mass 4 kg have the same radius. Then the ratio of moment of inertia of the disc about a tangent in its plane to the moment of inertia of the sphere about its tangent will be $\frac{x}{7}$. The value of x is _____. [25 Jan, 2023 (Shift-II)]

18. A light rope is wound around a hollow cylinder of mass 5 kg and radius 70 cm. The rope is pulled with a force of 52.5 N. The angular acceleration of the cylinder will be _____ rad s^{-2}. [13 April, 2023 (Shift-II)]

19. Match List-I with List-II [28 June, 2022 (Shift-I)]

	List-I		List - II
A.	Moment of inertia of solid sphere of radius R about any tangent.	I.	$\frac{5}{3}MR^2$
B.	Moment of inertia of hollow sphere of radius (R) about any tangent.	II.	$\frac{7}{5}MR^2$
C.	Moment of inertia of circular ring of radius (R) about its diameter.	III.	$\frac{1}{4}MR^2$
D.	Moment of inertia of circular disc of radius (R) about any diameter.	IV.	$\frac{1}{2}MR^2$

Choose the correct answer from the options given below:
(a) A-II, B-I, C-IV, D-III (b) A-I, B-II, C-IV, D-III
(c) A-II, B-I, C-III, D-IV (d) A-I, B-II, C-III, D-IV

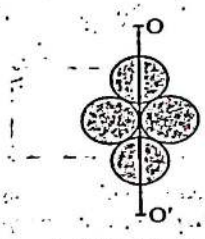
20. The radius of gyration of a cylindrical rod about an axis of rotation perpendicular to its length and passing through the centre will be _____ m. Given, the length of the rod is $10\sqrt{3}$m. [26 July, 2022 (Shift-I)]

21. Moment of Inertia (M.I.) of four bodies having same mass 'M' and radius '2R' are as follows: [25 June, 2022 (Shift-I)]
I_1 = M.I. of solid sphere about its diameter
I_2 = M.I. of solid cylinder about its axis
I_3 = M.I. of solid circular disc about its diameter
I_4 = M.I. of thin circular ring about its diameter
If $2(I_2+I_3)+I_4 = xI_1$ then the value of x will be _____.

22. The momentum of inertia of a uniform thin rod about a perpendicular axis passing through on end is I_1. The same rod is into a ring and its moment of inertia about a diameter is I_2. If $\frac{I_1}{I_2}$ is $\frac{x\pi^2}{3}$, then the value of x will be _____. [29 June, 2022 (Shift-I)]

23. The radius of gyration of a cylindrical rod about an axis of rotation perpendicular to its length and passing through the centre will be _____ m. Given, the length of the rod is $10\sqrt{3}$m. [26 July, 2022 (Shift-II)]

24. Four identical discs each of mass 'M' and diameter 'a' are arranged in a small plane as shown in figure. If the moment of inertia of the system about 'OO' is $\frac{x}{4}Ma^2$. Then, the value of x will be [28 July, 2022 (Shift-I)]



25. The radius of gyration of a cylindrical rod about an axis of rotation perpendicular to its length and passing through the centre will be _____ m. Given, the length of the rod is $10\sqrt{3}$m. [26 July, 2022 (Shift-II)]

@FAKE_CBSE_X_@_FORUM

Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.

Assertion (A): Moment of inertia of a circular disc 'M' and radius 'R' about X, Y axes (passing through its plane) and Z-axis which is perpendicular to its plane were found to be I_x, I_y and I_z respectively. The respective radii of gyration about all the three axes will be the same.

Reason (R): A rigid body making rotational motion has fixed mass and shape. In the light of the above statements, choose the most appropriate answer from the options given below:

[25 July, 2021 (Shift-I)]

(a) A is correct ssbut R is not correct.
(b) Both A and R are correct and R is the correct explanation of A.
(c) Both A and R are correct but R is NOT the correct explanation of A.
(d) A is not correct but R is correct.

27. A system consists of two identical spheres each of mass 1.5 kg and radius 50 cm at the end of light rod. The distance between the centres of the two spheres is 5 m. What will be the moment of inertia of the system about an axis perpendicular to the rod passing through its midpoint?

[31 Aug, 2021 (Shift-II)]

(a) 1.905×10^3 kgm^2 (b) 1.875×10^3 kgm^2
(c) 18.75 kgm^2 (d) 19.05 kgm^2

28.

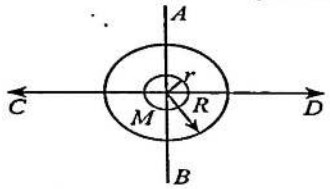
	List-I		List - II
A.	MI of the rod (length L, Mass M, about an axis $\perp$ to the rod Passing through the midpoint)	I.	8 ML^2 /3
B.	MI of the rod (length L, Mass $2M$, about an axis $\perp$ to the rod Passing through one of its end)	II.	ML^2/12
C.	MI of the rod (length $2L$, Mass M, about an axis $\perp$ to the rod Passing through its midpoint)	III.	ML^2/12
D.	MI of the rod (length $2L$, Mass $2M$, about an axis $\perp$ to the rod Passing through one of its end)	IV.	2ML^2/3

Choose the correct answer from the options given below:

[27 July, 2021 (Shift-I)]

(a) A → II, B → I, C → III, D → IV
(b) A → III, B → IV, C → II, D → I
(c) A → III, B → IV, C → II, D → I
(d) A → II, B → III, C → I, D → IV

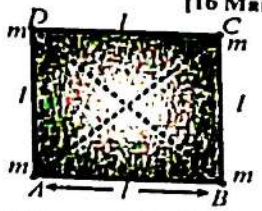
29. The figure shows two solid discs with radius R and r respectively. If mass per unit area is same for both, what is the ratio of MI of bigger disc around axis AB (which is $\perp$ to the plane of the disc and passing through its centre) to MI of smaller disc around one of its diameters lying on its plane? Given 'M' is the mass of the larger disc. (MI stands for moment of inertia) **[27 July, 2021 (Shift-I)]**



(a) $R^2 : r^2$ (b) $2r^4 : R^4$ (c) $2R^4 : r^4$ (d) $2R^2 : r^2$

30. Four equal masses, m each are placed at the corners of a square of length (l) as shown in the figure. The moment of inertia of the system about an axis passing through A and parallel to DB would be:

[16 March, 2021 (Shift-I)]



(a) $2ml^2$ (b) ml^2 (c) $\sqrt{3}ml^2$ (d) $3ml^2$

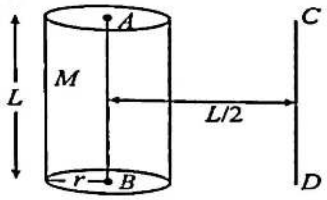
31. Four identical solid spheres each of mass 'm' and radius 'a' are placed with their centres on the four corners of a square of side 'b'. The moment of inertia of the system about side of square where the axis of rotation is parallel to the plane of the square is :

[26 Feb, 2021 (Shift-I)]

(a) $\frac{4}{5}ma^2$ (b) $\frac{4}{5}ma^2 + 2mb^2$
(c) $\frac{8}{5}ma^2 + 2mb^2$ (d) $\frac{8}{5}ma^2 + mb^2$

32. The solid cylinder of length 80 cm and mass M has a radius of 20 cm. Calculate the density of the material used if the moment of inertia of the cylinder about an axis CD parallel to AB as shown in figure is 2.7 kg m^2.

[26 Aug, 2021 (Shift-II)]



(a) 7.5×10^1 kg/m^3 (b) 1.49×10^2 kg/m^3
(c) 14.9 kg/m^3 (d) 7.5×10^2 kg/m^3

33. Moment of inertia of a square plate of side l about the axis passing through one of the corner and perpendicular to the plane of square plate is given by:

[27 Aug, 2021 (Shift-I)]

(a) Ml^2 (b) $\frac{Ml^2}{12}$ (c) $\frac{Ml^2}{6}$ (d) $\frac{2}{3}Ml^2$

34. Moment of inertia (M.I.) of four bodies, having same mass and radius, are reported as: **[24 Feb, 2021 (Shift-I)]**

I_1 = M.I. of thin circular ring about its diameter
I_2 = M.I. of circular disc about an axis perpendicular to disc and going through the centre,
I_3 = M.I. of solid cylinder about its axis and
I_4 = M.I. of solid sphere about its diameter.
Then

(a) $I_1 + I_3 < I_2 + I_4$ (b) $I_1 = I_2 = I_3 < I_4$
(c) $I_1 = I_2 = I_3 > I_4$ (d) $I_1 + I_2 = I_3 + \frac{5}{2}I_4$

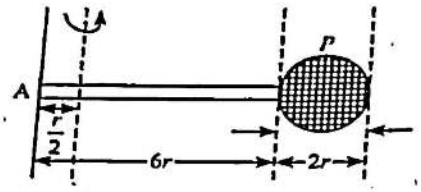
35. Consider a uniform wire of mass M and length L. It is bent into a semi-circle. Its moment of inertia about a line perpendicular to the plane of the wire passing through centre is: **[18 March, 2021 (Shift-II)]**

(a) $\frac{ML^2}{\pi^2}$ (b) $\frac{2ML^2}{5\pi^2}$ (c) $\frac{ML^2}{2\pi^2}$ (d) $\frac{ML^2}{4\pi^2}$

@AR_PHYSICS @RAJEDUNE

36. A uniform thin bar of mass 6 kg and length 2.4 meter is bent to make an equilateral hexagon. The moment of inertia about an axis passing through the centre of mass and perpendicular to the plane of hexagon is _____ $\times 10^{-1}$ kg m^2. [24 Feb, 2021 (Shift-II)]

37. Consider a badminton racket with length scales as shown in the figure. If the mass of the linear and circular portions of the badminton racket are same (M) and the mass of the threads are negligible, the moment of inertia of the racket about an axis perpendicular to the handle and in the plane of the ring at, $\frac{r}{2}$ distance from the end A of the handle will _____ Mr^2. [26 Aug, 2021 (Shift-I)]



38. Consider two uniform discs of the same thickness and different radii $R_1 = R$ and $R_2 = \alpha R$ made of the same material. If the ratio of their moments of inertia I_1 and I_2, respectively, about their axes is $I_1 : I_2 = 1 : 16$ then the value of α is: [4 Sep, 2020 (Shift-II)]

(a) 4 (b) $\sqrt{2}$ (c) 2 (d) $2\sqrt{2}$

39. The radius of gyration of a uniform rod of length ℓ, about an axis passing through a point $\frac{\ell}{4}$ away from the centre of the rod, an perpendicular to it is: [7 Jan, 2020 (Shift-I)]

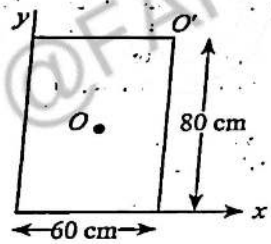
(a) $\frac{1}{8}\ell$ (b) $\sqrt{\frac{7}{48}}\ell$ (c) $\frac{1}{4}\ell$ (d) $\sqrt{\frac{3}{8}}\ell$

40. Mass per unit area of a circular disc of radius a depends on the distance r from its centre as $\sigma(r) = A + Br$. The moment of inertia of the disc about the axis, perpendicular to the plane passing through its centre is: [7 Jan, 2020 (Shift-II)]

(a) $2\pi a^4\left(\frac{aA}{4}+\frac{B}{5}\right)$ (b) $2\pi a^4\left(\frac{A}{4}+\frac{aB}{5}\right)$

(c) $\pi a^4\left(\frac{A}{4}+\frac{aB}{5}\right)$ (d) $2\pi a^4\left(\frac{A}{4}+\frac{B}{5}\right)$

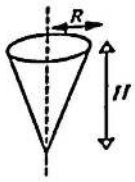
41. [4 Sep, 2020 (Shift-II)]



For a uniform rectangular sheet shown in the figure, the ratio of moments of inertia about the axes perpendicular to the sheet and passing through O (the centre of mass) and O' (corner point) is:

(a) 1/2 (b) 2/3 (c) 1/4 (d) 1/8

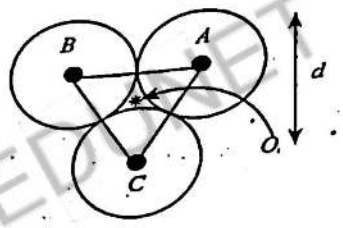
42. Shown in the figure is a hollow icecream cone (it is open at the top). If its mass is M, radius of its top, R and height, H, then its moment of inertia about its axis is: [6 Sep, 2020 (Shift-I)]



(a) $\frac{MR^2}{2}$ (b) $\frac{M\left(R^2+H^2\right)}{4}$

(c) $\frac{MH^2}{3}$ (d) $\frac{MR^2}{3}$

43. Three solid spheres each of mass m and diameter d are stuck tog such that the lines connecting the centres form an equilateral tria of side of length d. The ratio I_O/I_A of moment of inertia I_O of system about an axis passing the centroid and about center of of the spheres I_A and perpendicular to the plane of the triangle [9 Jan, 2020 (Shift



(a) $\frac{15}{13}$ (b) $\frac{13}{15}$ (c) $\frac{23}{13}$ (d) $\frac{13}{23}$

44. Moment of inertia of a cylinder of mass M, length L and radius about an axis passing through its centre and perpendicular to axis of the cylinder is $I = M\left(\frac{R^2}{4}+\frac{L^2}{12}\right)$. If such a cylinder is be made for a given mass of a material, the ratio L/R for it to ha minimum possible I is [3 Sep, 2020 (Shift-

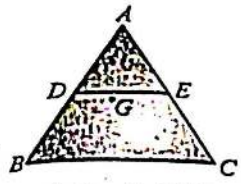
(a) $\frac{2}{3}$ (b) $\sqrt{\frac{3}{2}}$ (c) $\frac{3}{2}$ (d) $\sqrt{\frac{2}{3}}$

45. The linear mass density of a thin rod AB of length L varies from to B as $\lambda(x) = \lambda_0\left(1+\frac{x}{L}\right)$, where x is the distance from A. If M the mass of the rod then its moment of inertia about an axis pass through A and perpendicular to the rod is: [6 Sep, 2020 (Shift-I

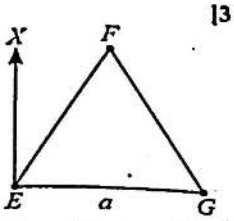
(a) $\frac{5}{12}ML^2$ (b) $\frac{7}{18}ML^2$ (c) $\frac{2}{5}ML^2$ (d) $\frac{3}{7}ML^2$

46. ABC is a plane lamina of the shape of an equilateral triangle. E are mid points of AB, AC and G is the centroid of the lami Moment of inertia of the lamina about an axis passing through and perpendicular to the plane ABC is I_0. If part ADE is remov the moment of inertia of the remaining part about the same axis $\frac{NI_0}{16}$ where N is an integer. Value of N is _____. [4 Sep, 2020 (Shift

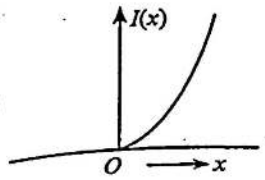
@FAKE_CBSE_@RAJ_EDURET

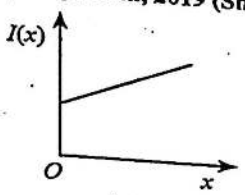


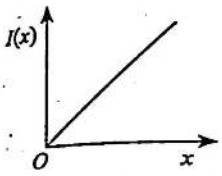
47. A massless equilateral triangle EFG of side 'a' (As shown in figure) has three particles of mass m situated at its vertices. The moment of inertia of the system about the line EX perpendicular to EG in the plane of EFG is $\frac{N}{20}ma^2$ where N is an integer. The value of N is _____. **[3 Sep, 2020 (Shift-II)]**

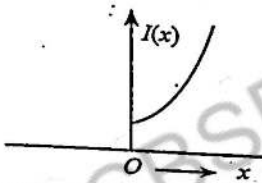


48. The moment of inertia of a solid sphere, about an axis parallel to its diameter and at a distance of x from it, is '$I(x)$'. Which one of the graphs represents the variation of $I(x)$ with x correctly? **[12 Jan, 2019 (Shift-II)]**

(a) 

(b) 

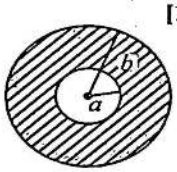
(c) 

(d) 

49. A solid sphere of mass M and radius R is divided into two unequal parts. The first part has a mass of $\frac{7M}{8}$ and is converted into a uniform disc of radius 2R. The second part is converted into a uniform solid sphere. Let I_1 be the moment of inertia of the disc about its axis and I_2 be the moment of inertia of the new sphere about its axis. The ratio I_1/I_2 is given by: **[10 April, 2019 (Shift-II)]**

(a) 185 (b) 65 (c) 285 (d) 140

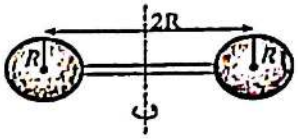
50. A circular disc of radius b has a hole of radius a at its centre (see figure). If the mass per unit area of the disc varies as $\rho = \rho_0/r$ then the radius of gyration of the disc about its axis passing through the centre is: **[12 April, 2019 (Shift-I)]**



(a) $\frac{a+b}{2}$ (b) $\frac{a+b}{3}$

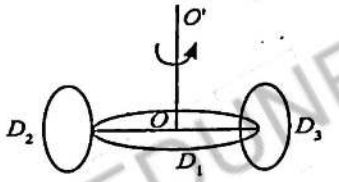
(c) $\sqrt{\frac{a^2+b^2+ab}{2}}$ (d) $\sqrt{\frac{a^2+b^2+ab}{3}}$

51. Two identical spherical balls of mass M and radius R each are stuck on two ends of a rod of length $2R$ and mass M (see figure). The moment of inertia of the system about the axis passing perpendicularly through the centre of the rod is: **[10 Jan, 2019 (Shift-II)]**



(a) $\frac{137}{15}MR^2$ (b) $\frac{17}{15}MR^2$ (c) $\frac{209}{15}MR^2$ (d) $\frac{152}{15}MR^2$

52. A circular disc D_1 of mass M and radius R has two identical discs D_2 and D_3 of the same mass M and radius R attached rigidly as its opposite ends (see figure). The moment of inertia of the system about the axis 'OO', passing through the centre of D_1 as shown in the figure, will: **[11 Jan, 2019 (Shift-II)]**

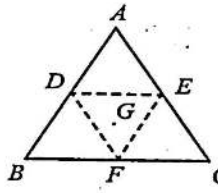


(a) MR^2 (b) $3MR^2$ (c) $\frac{4}{5}MR^2$ (d) $\frac{2}{3}MR^2$

53. A thin disc of mass M and radius R has mass per unit area $\sigma(r) = kr^2$ where r is the distance from its centre. Its moment of inertia about an axis going through its centre of mass and perpendicular to its plane is: **[10 April, 2019 (Shift-I)]**

(a) $\frac{MR^2}{2}$ (b) $\frac{MR^2}{3}$ (c) $\frac{MR^2}{6}$ (d) $\frac{2MR^2}{3}$

54. The equilateral triangle ABC is cut from a thin solid sheet of wood. (See figure) D, E and F are the mid points of its sides as shown and G is the centre of the triangle. The moment of inertia of the triangle about an axis passing through G and perpendicular to the plane of the triangle is I_0. If the smaller triangle DEF is removed from ABC, the moment of inertia of the remaining figure about the same axis is I. Then: **[11 Jan, 2019 (Shift-I)]**



(a) $I = \frac{15}{16}I_0$ (b) $I = \frac{3}{4}I_0$

(c) $I = \frac{9}{16}I_0$ (d) $I = \frac{I_0}{4}$

55. Let the moment of inertia of a hollow cylinder of length 30 cm (inner radius 10 cm and outer radius 20 cm), about its axis be I. The radius of a thin cylinder of the same mass such that its moment of inertia about its axis is also I, is: **[12 Jan, 2019 (Shift-I)]**

(a) 12 cm (b) 16 cm (c) 14 cm (d) 18 cm

@PHYSICS_CORSE_X@GMAIL.COM

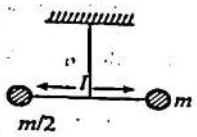
56. A thin circular plate of mass M and radius R has its density varying as $\rho(r) = \rho_0 r$ with ρ_0 as constant and r is the distance from its centre. The moment of inertia of the circular plate about an axis perpendicular to the plate and passing through its edge is $I = aMR^2$. The value of the coefficient a is: [8 April, 2019 (Shift-1)]

(a) $\frac{3}{2}$ (b) $\frac{1}{2}$ (c) $\frac{3}{5}$ (d) $\frac{8}{5}$

57. A thin disc of mass M and radius R has mass per unit area $\sigma(r) = kr^2$ where r is the distance from its centre. Its moment of inertia about an axis going through its centre of mass and perpendicular to its plane is: [10 April, 2019 (Shift-1)]

(a) $\frac{MR^2}{2}$ (b) $\frac{MR^2}{3}$ (c) $\frac{MR^2}{6}$ (d) $\frac{2MR^2}{3}$

58. Two masses m and $\frac{m}{2}$ are connected at the two ends of a massless rigid rod of length l. The rod is suspended by a thin wire of torsional constant k at the centre of mass of the rod-mass system (see figure). Because of torsional constant k, the restoring torque is $\tau = k\theta$ for angular displacement θ. If the rod is rotated by θ_0 and released, the tension in it when it passes through its mean position will be [9 Jan, 2019 (Shift-I)]



(a) $\frac{3k\theta_0^2}{l}$ (b) $\frac{2k\theta_0^2}{l}$ (c) $\frac{k\theta_0^2}{l}$ (d) $\frac{k\theta_0^2}{2l}$

Torque & Angular Momentum

59. A uniform rod AB of mass 2 kg and Length 30 cm at rest on a smooth horizontal surface. An impulse of force 0.2 Ns is applied to end B. The time taken by the rod to turn through at right angles will be $\frac{\pi}{x}s$, where $x =$ _____. [1 Feb, 2024 (Shift-II)]

60. A string is wrapped around the rim of a wheel of moment of inertia 0.40 kgm² and radius 10 cm. The wheel is free to rotate about its axis. Initially the wheel is at rest. The string is now pulled by a force of 40 N. The angular velocity of the wheel after 10 s is x rad/s, where x is _____. [09 April, 2024 (Shift-I)]

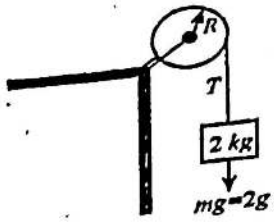
61. A force of $-P\hat{k}$ acts on the origin of the coordinate system. The torque about the point $(2, -3)$ is $P(a\hat{i} + b\hat{j})$, the ratio of $\frac{a}{b}$ is $\frac{x}{2}$. The value of x is [10 April, 2023 (Shift-II)]

62. A pulley of radius 1.5 m is rotated about its axis by a force $F = (12t - 3t^2)N$ applied tangentially (while t is measured in seconds). If moment of inertia of the pulley about its axis of rotation is 4.5 kg m², the number of rotations made by the pulley before its direction of motion is reversed, will be $\frac{K}{\pi}$. The value of K is [27 July, 2022 (Shift-I)]

63. The torque of a force $5\hat{i} + 3\hat{j} - 7\hat{k}$ about the origin is τ. If the force acts on p article whose position vector is $2\hat{i} + 2\hat{j} + \hat{k}$, then the value of τ will be [29 July, 2022 (Shift-II)]

(a) $11\hat{i} + 19\hat{j} - 4\hat{k}$ (b) $-11\hat{i} + 9\hat{j} - 16\hat{k}$
(c) $-17\hat{i} + 19\hat{j} - 4\hat{k}$ (d) $17\hat{i} + 9\hat{j} + 16\hat{k}$

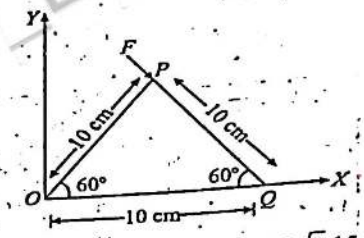
64. A uniform disc with mass M = 4 kg and radius R = 10 cm is mounted on a fixed horizontal axle as shown in figure. A block with mass m = 2 kg hangs from a massless cord that is wrapped around the rim of the disc. During the fall of the block, the cord does not slip and there is no friction at the axle. The tension in the cord is _____N. [28 June, 2022 (Shift-I)]



65. A cord is wound round the circumference of wheel of radius r. The axis of the wheel is horizontal and the moment of inertia about it is I. A weight mg is attached to the cord at the end. The weight falls from rest. After falling through a distance 'h', the square of angular velocity of wheel will be: [26 Feb, 2021 (Shift-I)]

(a) $\frac{2mgh}{I + mr^2}$ (b) $2gh$ (c) $\frac{2gh}{I + mr^2}$ (d) $\frac{2mgh}{I + 2mr^2}$

66. A triangular plate is shown. A force $\vec{F} = 4\hat{i} - 3\hat{j}$ is applied at point P. The torque at point P with respect to point 'O' and 'Q' are: [17 March, 2021 (Shift-I)]

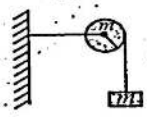


(a) $-15+20\sqrt{3}, 15+20\sqrt{3}$ (b) $15-20\sqrt{3}, 15+20\sqrt{3}$
(c) $15+20\sqrt{3}, 15-20\sqrt{3}$ (d) $-15-20\sqrt{3}, 15-20\sqrt{3}$

67. A solid disc of radius 20 cm and mass 10 kg is rotating with angular velocity of 600rpm, about an axis normal to its circular plane and passing through its centre of mass. The retarding torque required to bring the disc at rest in 10 s is _____ $\pi \times 10^{-1}$ Nm. [25 July, 2021 (Shift-II)]

68. A force $\vec{F} = 4\hat{i} + 3\hat{j} + 4\hat{k}$ is applied on an intersection point of $x = 2$ plane and x-axis. The magnitude of torque of this force about a point (2, 3, 4) is _____. (Round off to the Nearest Integer) [16 March, 2021 (Shift-II)]

69. As shown in the figure, a bob a mass m is tied by a massless string whose other end portion is wound on a fly wheel (disc) of radius r and mass m. When released from rest, the bob starts falling vertically. When it has covered a distance of h, the angular speed of the wheel will be : [7 Jan, 2020 (Shift-I)]

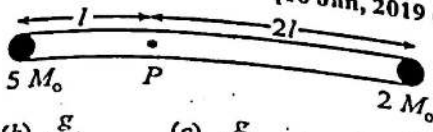


(a) $r\sqrt{\frac{3}{4gh}}$ (b) $\frac{1}{r}\sqrt{\frac{2gh}{3}}$ (c) $r\sqrt{\frac{3}{2gh}}$ (d) $\frac{1}{r}\sqrt{\frac{4gh}{3}}$

@FAKECBSE_K @RAJ_EDUNET

70. A force $\vec{F} = (\hat{i} + 2\hat{j} + 3\hat{k})$ N acts at a point $(4\hat{i} + 3\hat{j} - \hat{k})$ m. Then the magnitude of torque about the point $(\hat{i} + 2\hat{j} + \hat{k})$ m will be $\sqrt{x}$ N - m. The value of x is
[5 Sep, 2020 (Shift-I)]
(a) 195 (b) 165 (c) 105 (d) 135

71. A rigid massless road of length $3l$ has tow masses attached at each end as shown in the figure. The rod is pivoted at point P on the horizontal axis (see figure). When released from initial horizontal position, its instantaneous angular acceleration will be :
[10 Jan, 2019 (Shift-II)]



(a) $\frac{g}{13l}$ (b) $\frac{g}{3l}$ (c) $\frac{g}{2l}$ (d) $\frac{7g}{3l}$

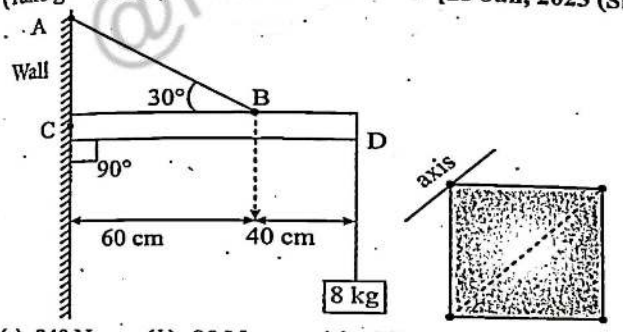
72. A particle of mass m is moving along a trajectory given by
$x = x_0 + a\cos\omega_1 t$
$y = y_0 + b\sin\omega_2 t$
The torque, acing on the particle about the origin, at $t = 0$ is:
[10 April, 2019 (Shift-I)]
(a) $my_0 a\omega_1^2 \hat{k}$ (b) $m(-x_0 b + y_0 a)\omega_1^2 \hat{k}$
(c) $-m(-x_0 b\omega_2^2 - y_0 a\omega_1^2)\hat{k}$ (d) Zero

Rotational/Equilibrium &Toppling

73. A heavy iron bar of weight 12 kg is having its one end on the ground and the other on the shoulder of a man. The rod makes an angle 60° with the horizontal, the weight experienced by the man is:
[27 JAN, 2024 (Shift-II)]
(a) 6 kg (b) 12 kg (c) 3 kg (d) $6\sqrt{3}$ kg

74. A heavy iron bar, of weight W is having its one end on the ground and the other on the shoulder of a person. The bar makes an angle θ with the horizontal. The weight experienced by the person is:[09 April, 2024 (Shift-I)]
(a) $W/2$ (b) W (c) $W\cos\theta$ (d) $W\sin\theta$

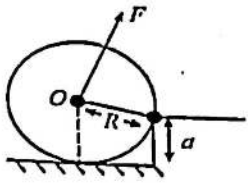
75. An object of mass 8 kg is hanging from one end of a uniform rod CD of mass 2 kg and length 1m pivoted at its end C on a vertical wall as shown in figure below. It is supported by a cable AB such that the system is in equilibrium. The tension in the cable is :
(Take g = 10m/s²)
[25 Jan, 2023 (Shift-I)]



(a) 240 N (b) 90 N (c) 300 N (d) 30 N

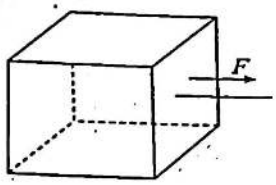
76. A metre scale is balanced on a knife edge at its centre. When two coins, each of mass 10 g are put one on the top of the other at the 10.0 cm mark the scale is found to be balanced at 40.0 cm mark. The mass of the metre scale is found to be $x \times 10^{-2}$ kg. The value of x is _____.
[24 June, 2022 (Shift-I)]

77. A uniform cylinder of mass M and radius R is to be pulled over a step of height a ($a < R$) by applying a force F at its centre 'O' perpendicular to the plane through the axes of the cylinder on the edge of the step (see figure). The minimum value of F required is:
[2 Sep, 2020 (Shift-I)]

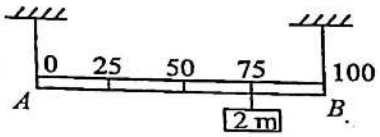


(a) $Mg\sqrt{1-\frac{a^2}{R^2}}$ (b) $Mg\sqrt{1-\left(\frac{R-a}{R}\right)^2}$
(c) $Mg\sqrt{\left(\frac{R}{R-a}\right)^2 - 1}$ (d) $Mg\frac{a}{R}$

78. Consider uniform cubical box of side a on a rough floor that is to be moved by applying minimum possible force F at a point b above its centre of mass (see figure). If the coefficient of friction is $\mu = 0.4$, the maximum possible value of $100 \times \frac{b}{a}$ for box not to topple before moving is_____.
[7 Jan, 2020 (Shift-II)]



79. Shown in the figure is rigid and uniform one meter long rod AB held in horizontal position by two strings tied to its ends and attached to the ceiling. The rod is of mass 'm' and has another weight of mass 2m hung at a distance of 75 cm from A. The tension in the string at A is:
[2 Sep, 2020 (Shift-I)]

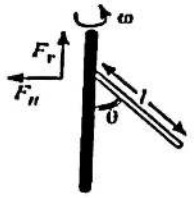


(a) 0.75 mg (b) 1 mg (c) 2 mg (d) 0.5 mg

80. Put a uniform meter scale horizontally on your extended index fingers with the left one at 0.00 cm and the right one at 90.00 cm. When you attempt to move both the fingers slowly towards the center, initially only the left finger slips with respect to the scale and the right finger does not. After some distance the left finger stops and the right one starts slipping. Then the right finger stops at a distance x_R from the center (50.00 cm) of the scale and the let one starts slipping again. This happens because of the difference in the frictional forces on he two fingers. If the coefficients of static and dynamic friction between the fingers and the scale are 0.40 and 0.32, respectively, the value of x_R (in cm) is _____
[JEE Adv, 2020]

@PHYSICSBOOK@RAJ_EDUNET

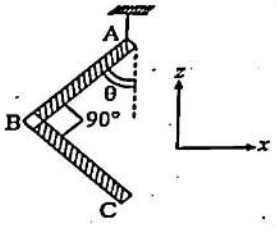
81. A uniform rod of length 'l' is pivoted at one of its ends on a vertical shaft of negligible radius. When the shaft rotates at angular speed ω the rod makes an angle with it (see figure). To find θ equate the rate of change of angular momentum (direction going into the paper) $\frac{ml^2}{12}\omega^2 \sin\theta\cos\theta$ about the centre of mass (CM) to the torque provided by the horizontal and vertical forces F_H and F_V about the CM. The value of θ is then such that: [3 Sep, 2020 (Shift-II)]



(a) $\cos\theta = \frac{g}{l\omega^2}$ (b) $\cos\theta = \frac{2g}{3l\omega^2}$

(c) $\cos\theta = \frac{3g}{2l\omega^2}$ (d) $\cos\theta = \frac{g}{2l\omega^2}$

82. An L-shaped object, made of thin rods of uniform mass density, is suspended with a string as shown in figure. If AB = BC, and the angle made by AB with downward vertical is θ, then: [9 Jan, 2019 (Shift-I)]



(a) $\tan\theta = \frac{1}{2\sqrt{3}}$ (b) $\tan\theta = \frac{1}{2}$

(c) $\tan\theta = \frac{2}{\sqrt{3}}$ (d) $\tan\theta = \frac{1}{3}$

Conservation of Angular Momentum

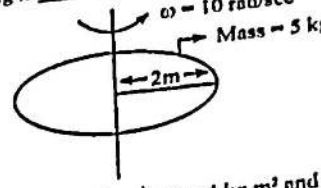
83. A body of mass 5 kg moving with a uniform speed $3\sqrt{2}$ ms^{-1} in X–Y plane along the line $y = x + 4$. The angular momentum of the particle about the origin will be _____ kg m^{2}s^{-1}. [29 Jan, 2024 (Shift-II)]

84. A particle of mass m projected with a velocity 'u' making an angle of 30° with the horizontal. The magnitude of angular momentum of the projectile about the point of projection when the particle is at its maximum height h is: [30 Jan, 2024 (Shift-I)]

(a) $\frac{\sqrt{3}}{16}\frac{mu^3}{g}$ (b) $\frac{\sqrt{3}}{2}\frac{mu^2}{g}$

(c) $\frac{mu^3}{\sqrt{2}g}$ (d) zero

85. Consider a Disc of mass 5 kg, radius 2m, rotating with angular velocity of 10 rad/s about an axis perpendicular to the plane of rotation. An identical disc is kept gently over the rotating disc along the same axis. The energy dissipated so that both the discs continue to rotate together without slipping is _____ J. [30 Jan, 2024 (Shift-I)]



86. Two discs of moment of inertia $I_1 = 4$ kg m^2 and $I_2 = 2$kg m^2 about their central axes & normal to their planes, rotating with angular speeds 10 rad/s & 4 rad/s respectively are brought into contact face to face with their axe of rotation coincident. The loss in kinetic energy of the system in the process is _____ J. [30 Jan, 2024 (Shift-I)]

87. A body of mass 'm' is projected with a speed 'u' making an angle of 45° with the ground. The angular momentum of the body about the point of projection, at the highest point is expressed as $\frac{\sqrt{2}mu^3}{Xg}$. The value of 'X' is _____. [31 Jan, 2024 (Shift-I)]

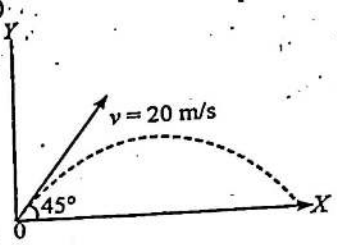
88. If the radius of earth is reduced to three-fourth of its present value without change in its mass then value of duration of the day of earth will be _____ hours 30 minutes. [06 April, 2024 (Shift-I)]

89. A thin circular disc of mass M and radius R is rotating in a horizontal plane about an axis passing through its centre and perpendicular to its plane with angular velocity ω. If another disc of same dimensions but of mass $M/2$ is placed gently on the first disc co-axially, then the new angular velocity of the system is: [08 April, 2024 (Shift-I)]

(a) $\frac{4}{5}\omega$ (b) $\frac{5}{4}\omega$ (c) $\frac{2}{3}\omega$ (d) $\frac{3}{2}\omega$

90. A particle of mass 100 g is projected at time $t = 0$ with a speed $20ms^{-1}$ at an angle 45° with the horizontal as given in the figure. The magnitude of the angular momentum of the particle about the starting point at time $t = 2s$ is found to be $\sqrt{K}\ kgm^2/s$. The value of K is _____ [29 Jan, 2023 (Shift-I)]

(Take g = $10ms^{-2}$)



91. If the earth suddenly shrinks to $\frac{1}{64}$ th of its original volume with mass remaining the same, the period of rotation of earth becomes $\frac{24}{x}h$. The value of x is [10 April, 2023 (Shift-I)]

92. A solid sphere of mass 500 g and radius 5 cm is rotated about one of its diameter with angular speed of 10 rad s^{-1}. If the moment of inertia of the sphere about its tangent is $x \times 10^{-2}$ times its angular momentum about the diameter. Then the value of x will be _____. [11 April, 2023 (Shift-I)]

@FAKE_CBSE_X_@PHYSICSWALLAH

94. A solid sphere is rolling on a horizontal plane without slipping. If the ratio of angular momentum about axis of rotation of the sphere to the total energy of moving sphere is $\pi : 22$ then, the value of its angular speed will be _____ rad/s. **[13 April, 2023 (Shift-I)]**

95. A circular plate is rotating in horizontal plane, about an axis passing through its center and perpendicular to the plate, with an angular velocity ω A person sits at the center having two dumbbells in his hands. When he stretches out his hands, the moment of inertia of the system becomes triple. If E be the initial Kinetic energy of the system, then final Kinetic energy will be $\frac{E}{x}$. The value of x is

[11 April, 2023 (Shift-II)]

96. A bar of mas $M = 1.00$ kg and length $L = 0.20$ m is lying on a horizontal frictionless surface. One end of the bar is pivoted at a point about which it is free to rotate. A small mass $m = 0.10$ kg is moving on the same horizontal surface with 5.00 ms^{-1} speed on a path perpendicular to the bar. It hits the bar at a distance $L/2$ from the pivoted end and returns back on the same path with speed v. After this elastic collision, the bar rotates with an angular velocity ω. Which of the following statement is correct? **[JEE Adv, 2023]**

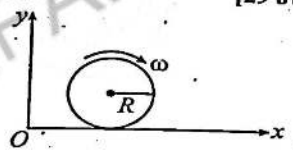
(a) $\omega = 6.98$ rad s^{-1} and $v = 4.30$ m s^{-1}
(b) $\omega = 3.75$ rad s^{-1} and $v = 4.30$ m s^{-1}
(c) $\omega = 3.75$ rad s^{-1} and $v = 10.0$ m s^{-1}
(d) $\omega = 6.80$ rad s^{-1} and $v = 4.10$ m s^{-1}

96. A thin circular ring of mass M and radius R is rotating with a constant angular velocity 2 $rads^{-1}$ in a horizontal plane about an axis vertical to its plane and passing through the centre of the ring. If two objects each of mass m be attached gently to the opposite ends of a diameter of ring, the will then rotate with an angular velocity (in $rads^{-1}$). **[26 June, 2022 (Shift-I)]**

(a) $\frac{M}{(M+m)}$ (b) $\frac{(M+2m)}{2M}$ (c) $\frac{2M}{(M+2m)}$ (d) $\frac{2(M+2m)}{M}$

97. The position vector of 1 kg object is $\vec{r} = (3\hat{i} - \hat{j})$ m and its velocity $\vec{v} = (3\hat{j} - \hat{k})$ ms^{-1}. The magnitude of its angular momentum is $\sqrt{x}$ Nm where x is _____. **[28 June, 2022 (Shift-I)]**

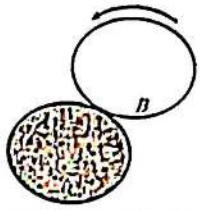
98. A spherical shell of 1 kg mass and radius R is rolling with angular speed ω on horizontal plane (as shown in figure). The magnitude of angular momentum of the shell about the origin O is $\frac{a}{3}R^2\omega$. The value of a will be: **[29 June, 2022 (Shift-I)]**



(a) 2 (b) 3 (c) 5 (d) 4

99. A particle of mass 1 kg is subjected to a force which depends on the position as with $\vec{F} = -k(x\hat{i} + y\hat{j})$ kg ms^{-2}. At time $t = 0$, the particle's position $\vec{r} = \left(\frac{1}{\sqrt{2}}\hat{i} + \sqrt{2}\hat{j}\right)$ m and its velocity $\vec{v} = \left(-\sqrt{2}\hat{i} + \sqrt{2}\hat{j} + \frac{2}{\pi}\hat{k}\right)$ ms^{-1}. Let v_x and v_y denote the x and the y components of the particle's velocity, respectively. Ignore gravity. When $z = 0.5$ m, the value of $(xv_y - yv_x)$ is _____ $m^2 s^{-1}$. **[JEE Adv, 2022]**

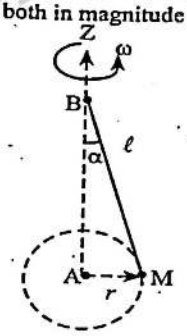
100. A flat surface of a thin uniform disk A of radius R is glued to a horizontal table. Another thin uniform disk B of mass M and with the same radius R rolls without slipping on the circumference of A, as shown in the figure. A flat surface of B also lies on the plane of the table. The center of mass of B has fixed angular speed ω about the vertical axis passing through the center of A. The angular momentum of B is $nM\omega R^2$ with respect to the center of A. Which of the following is the value of n? **[JEE Adv, 2022]**



(a) 2 (b) 5 (c) 7/2 (d) 9/2

101. A mass M hangs on a massless rod of length ℓ which rotates at a constant angular frequency. The mass M moves with steady speed in a circular path of constant radius. Assume that the system is in steady circular motion with constant angular velocity ω. The angular momentum of M about point A is L_A which lies in the positive z direction and the angular momentum of M about point B is L_B. The correct statement for this system is: **[17 March, 2021 (Shift-I)]**

(a) L_A is constant, both in magnitude and direction
(b) L_B is constant in direction with varying magnitude
(c) L_A and L_B are both constant in magnitude and direction
(d) L_B is constant, both in magnitude and direction



102. Angular momentum of a single particle moving with constant speed along circular path: **[31 Aug, 2021 (Shift-I)]**

(a) remains same in magnitude but changes in the direction
(b) changes in magnitude but remains same in the direction
(c) remains same in magnitude and direction
(d) is zero

103. A particle of mass 'm' is moving in time 't' on a trajectory given by **[25 July, 2021 (Shift-I)]**

$\vec{r} = 10\alpha t^2\hat{i} + 5\beta(t-5)\hat{j}$

Where α and β are dimensional constants.

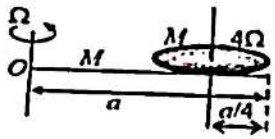
The angular momentum of the particle become the same as it was for $t = 0$ at time $t =$ _____ seconds.

104. A thin rod of mass M and length a is free to rotate in horizontal plane about a fixed vertical axis passing through point O. A thin circular disc of mass M and of radius $a/4$ is pivoted on this rod with its center at a distance $a/4$ from the free end so that it can rotate freely about its vertical axis, as shown in the figure. Assume that both the rod and the disc have uniform density and they remain horizontal during the motion. An outside stationary observer finds

@FAKE_CBSE_X @RAJ_SIR_OFFICIAL

the rod rotating with an angular velocity Ω and the disc rotating about its vertical axis with angular velocity $4\,\Omega$. The total angular momentum of the system about the point O is $\left(\frac{Ma^2\Omega}{48}\right)n$. The value of n is.

[JEE Adv, 2021]



105. A thin circular ring of mass M and radius r is rotating about its axis with an angular speed ω. Two particles having mass m each are now attached at diametrically opposite points. The angular speed of the ring will become:

[18 March, 2021 (Shift-I)]

(a) $\omega\frac{M-2m}{M+2m}$ (b) $\omega\frac{M+2m}{M}$

(c) $\omega\frac{M}{M+m}$ (d) $\omega\frac{M}{M+2m}$

106. Two discs have moments of intertia I_1 and I_2 about their respective axes perpendicular to the plane and passing through the centre. They are rotating with angular speeds, ω_1 and ω_2 respectively and are brought into contact face to face with their axes of rotation coaxial. The loss in kinetic energy of the system in the process is given by:

[27 Aug, 2021 (Shift-II)]

(a) $\frac{(I_1-I_2)^2\omega_1\omega_2}{2(I_1+I_2)}$ (b) $\frac{I_1I_2}{(I_1+I_2)}(\omega_1-\omega_2)^2$

(c) $\frac{I_1I_2}{2(I_1+I_2)}(\omega_1-\omega_2)^2$ (d) $\frac{(\omega_1-\omega_2)^2}{2(I_1+I_2)}$

107. Four point masses, each of mass m, are fixed at the corners of a square of side ℓ. The square is rotating with angular frequency ω, about an axis passing through one of the corners of the square and parallel to its diagonal, as shown in the figure. The angular momentum of the square about this axis is

[06 Sep, 2020 (Shift-I)]

(a) $3\,m\ell^2\omega$ (b) $5\,m\ell^2\omega$ (c) $m\ell^2\omega$ (d) $2\,m\ell^2\omega$

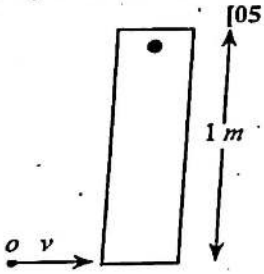
108. Consider a uniform rod of mass $M=4m$ and length ℓ pivoted about its centre. A mass m moving with velocity v making angle $\theta=\frac{\pi}{4}$ to the rod's long axis collides with one end of the rod and sticks to it. The angular speed of the rod-mass system just after the collision is:

[8 Jan, 2020 (Shift-I)]

(a) $\frac{4v}{7\ell}$ (b) $\frac{3\sqrt{2}}{7}\frac{v}{\ell}$ (c) $\frac{3}{7}\frac{v}{\ell}$ (d) $\frac{3}{7\sqrt{2}}\frac{v}{\ell}$

109. A thin rod of mass 0.9 kg and length 1 m is suspended, at rest, from one end so that it can freely oscillate in the vertical plane. A particle of mass 0.1 kg moving in a straight line with velocity 80 m/s hits the rod at its bottom most point and sticks to it (see figure). The angular speed (in rad/s) of the rod immediately after the collision will be

[05 Sep, 2020 (Shift-II)]



110. A person of 80 kg mass is standing on the rim of a circular platform of mass 200 kg rotating about its axis at 5 revolutions per minute (rpm). The person now starts moving towards the centre of the platform. What will be the rotational speed (in rpm) of the platform when the person reaches its centre _____.

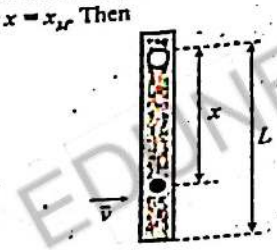
[03 Sep, 2020 (Shift-I)]

111. A circular disc of mass M and radius R is rotating about its axis with angular speed ω_1. If another stationary disc having radius $\frac{R}{2}$ and same mass M is dropped co-axially on to the rotating disc. Gradually both discs attain constant angular speed ω_2. The energy lost in the process is $p\%$ of the initial energy. Value of p is _____.

[04 Sep, 2020 (Shift-I)]

112. A rod of mass m and length L, pivoted at one of its ends, is hanging vertically. A bullet of the same mass moving at speed v strikes the rod horizontally at a distance x from its pivoted end and gets embedded in it. The combined system now rotates with angular speed ω about the pivot. The maximum angular speed ω_M is achieved for $x=x_M$. Then

[JEE Adv, 2021]



(a) $\omega=\frac{3vx}{L^2+3x^2}$ (b) $\omega=\frac{12vx}{L^2+12x^2}$

(c) $x_M=\frac{L}{\sqrt{3}}$ (d) $\omega_M=\frac{v}{2L}\sqrt{3}$

113. A wheel is rotating freely with an angular speed ω on a shaft. The moment of inertia of the wheel is I and the moment of inertia of the shaft is negligible. Another wheel of moment of inertia $3I$ initially at rest is suddenly coupled to the same shaft. The resultant fractional loss in the kinetic energy of the system is

[5 Sep, 2020 (Shift-I)]

(a) $\frac{5}{6}$ (b) $\frac{1}{4}$ (c) 0 (d) $\frac{3}{4}$

114. Two uniform circular discs are rotating independently in the same direction around their common axis passing through their centres. The moment of inertia and angular velocity of the first disc are 0.1 kg-m^2 and 10 rad s^{-1} respectively while those for the second one are 0.2 kg-m^2 and 5 rad s^{-1} respectively. At some instant they get stuck together and start rotating as a single system about their common axis with some angular speed. The kinetic energy of the combined system is

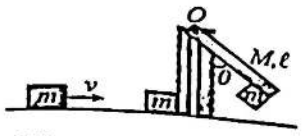
[2 Sep, 2020 (Shift-II)]

(a) $\frac{20}{3}$J (b) $\frac{5}{3}$J (c) $\frac{10}{3}$J (d) $\frac{2}{3}$J

115. A block of mass $m = 1$ kg slides with velocity $v = 6$ m/s on a frictionless horizontal surface and collides with a uniform vertical rod and sticks to it as shown. The rod is pivoted about O and swings as a result of the collision making angle θ before momentarily coming to rest. If the rod has mass $M = 2$ kg and length $l = 1$ m, the value of θ is approximately (take $g = 10$ m/s^2)

[3 Sep, 2020 (Shift-I)]

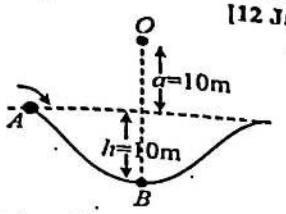
@FAKE_CB @RALEDUNET



(a) 49° (b) 55° (c) 63° (d) 69°

116. A particle of mass 20 g is released with an initial velocity 5 m/s along the curve from the point A, as shown in the figure. The point A is at height h from point B. The particle slides along the frictionless surface. When the particle reaches point B, its angular momentum about O will be: [Take $g = 10$ m/s^2]

[12 Jan, 2019 (Shift-II)]



(a) 2 kg-m^2/s (b) 8 kg-m^2/s (c) 6 kg-m^2/s (d) 3 kg-m^2/s

117. A thin smooth rod of length L and mass M is rotating freely with angular speed ω_0 about an axis perpendicular to the rod and passing through its centre. Two beads of mass m and negligible size are at the centre of the rod initially. The beads are free to slide along the rod. The angular speed of the system, when the beads reach the opposite ends of the rod, will be: **[9 April, 2019 (Shift-II)]**

(a) $\frac{M\omega_0}{M+3m}$ (b) $\frac{M\omega_0}{M+m}$ (c) $\frac{M\omega_0}{M+2m}$ (d) $\frac{M\omega_0}{M+6m}$

118. A person of mass M is, sitting on a swing of length L and swinging with an angular amplitude θ_0. If the person stands up when the swing passes through its lowest point, the work done by him, assuming that his centre of mass moves by a distance $\ell(\ell << L)$, is close to **[12 April, 2019 (Shift-I)]**

(a) $Mg\ell$ (b) $Mg\ell(1+\theta_0^2)$

(c) $Mg\ell\left(1-\theta_0^2\right)$ (d) $Mg\ell\left(1+\frac{\theta_0^2}{2}\right)$

119. Two coaxial discs, having moments of inertia I_1 and $\frac{I_1}{2}$, are rotating with respectively angular velocities ω_1 and $\frac{\omega_1}{2}$, about their common axes. They are brought in contact with each other and thereafter they rotate with a common angular velocity. If E_f and E_i are the final and initial total energies, then $(E_f - E_i)$ is:

[10 April, 2019 (Shift-I)]

(a) $-\frac{I_1\omega_1^2}{12}$ (b) $\frac{3}{8}I_1\omega_1^2$ (c) $\frac{I_1\omega_1^2}{6}$ (d) $-\frac{I_1\omega_1^2}{24}$

Combined Rotation and Translation, Rolling Motion

120. A ring and a solid sphere roll down the same inclined plane without slipping. They start from rest. The radii of both bodies are identical and the ratio of their kinetic energies is $\frac{7}{x}$ where x is _____.

[27 Jan, 2024 (Shift-II)]

121. A cylinder is rolling down on an inclined plane of inclination 60°. It's acceleration during rolling down will be $\frac{x}{\sqrt{3}}$ m/s^2, where x = _____. (use $g = 10$ m/s^2). **[29 Jan, 2024 (Shift-I)]**

122. A solid circular disc of mass 50 kg rolls along a horizontal floor so that its center of mass has a speed of 0.4 m/s. The absolute value of work done on the disc to stop it is _____ J. **[31 Jan, 2024 (Shift-I)]**

123. A disc of radius R and mass M is rolling horizontally without slipping with speed v. It then moves up an inclined smooth surface as shown in figure. The maximum height that the disc can go up the incline is: **[1 Feb, 2024 (Shift-II)]**

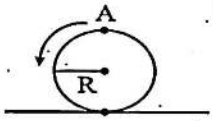
(a) $\frac{v^2}{g}$ (b) $\frac{3}{4}\frac{v^2}{g}$ (c) $\frac{1}{2}\frac{v^2}{g}$ (d) $\frac{2}{3}\frac{v^2}{g}$

124. A solid sphere and a hollow cylinder roll up without slipping on same inclined plane with same initial speed v. The sphere and the cylinder reaches upto maximum heights h_1 and h_2, respectively, above the initial level. The ratio $h_1 : h_2$ is $\frac{n}{10}$. The value of n is_____. **[04 April, 2024 (Shift-I)]**

125. A hollow sphere is rolling on a plane surface about its axis of symmetry. The ratio of rotational kinetic energy to its total kinetic energy is $x/5$. The value of x is _____. **[05 April, 2024 (Shift-II)]**

126. A circular disc reaches from top to bottom of an inclined plane of length l. When it slips down the plane, if takes ts. When it rolls down the plane then it takes $\left(\frac{\alpha}{2}\right)^{1/2} t$s, where α is ..... **[09 April, 2024 (Shift-II)]**

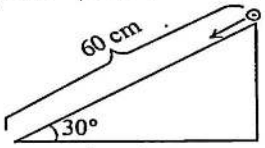
127. A disc is rolling without slipping on a surface. The radius of the disc is R. At $t = 0$, the top most point on the disc is A as shown in figure. When the disc completes half of its rotation, the displacement of point A from its initial position is **[13 April, 2023 (Shift-I)]**



(a) $R\sqrt{(\pi^2+4)}$ (b) $R\sqrt{(\pi^2+1)}$

(c) $2R$ (d) $2R\sqrt{(1+4\pi^2)}$

128. A solid cylinder is released from rest from the top of an inclined plane of inclination 30° and length 60 cm. If the cylinder rolls without slipping, its speed upon reaching the bottom of the inclined plane is _____ ms^{-1}. (Given g = 10 ms^{-1}) **[1 Feb, 2023 (Shift-I)]**



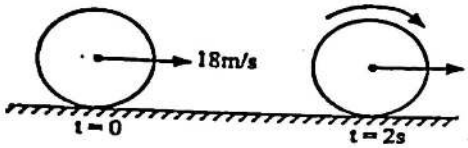
CRACK_OBSER@RAJ_BHNET

129. A thin uniform rod of length 2 m, cross sectional area 'A' and density 'd' is rotated about an axis passing through the centre and perpendicular to its length with angular velocity ω. If value of ω in terms of its rotational kinetic energy E is $\sqrt{\frac{\alpha E}{Ad}}$ then the value of α is

[30 Jan, 2023 (Shift-I)]

130. A uniform disc of mass 0.5 kg and radius r is projected with velocity 18 m/s at $t = 0$ s on a rough horizontal surface. It starts off with a purely sliding motion at $t = 0$ s. After 2 s it acquires a purely rolling motion (see figure). The total kinetic energy of the disc after 2 s will be _____ J (given, coefficient of friction is 0.3 and $g = 10$ m/s^2)

[30 Jan, 2023 (Shift-II)]



131. For a rolling spherical shell, the ratio of rotational kinetic energy and total kinetic energy is $\frac{x}{5}$. The value of x is _____.

[12 April, 2023 (Shift-I)]

132. A solid sphere of mass 1 kg rolls without slipping on a plane surface. Its kinetic energy is 7×10^{-3} J. The speed of the centre of mass of the sphere is _____ cm s^{-1}.

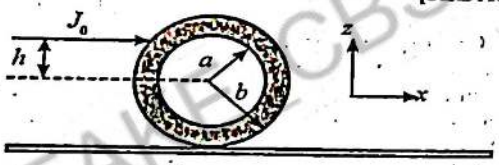
[31 Jan, 2023 (Shift-I)]

133. A solid sphere of mass 2 kg is making pure rolling on a horizontal surface with kinetic energy 2240 J. The velocity of centre of mass of the sphere will be _____ ms^{-1}.

[29 Jan, 2023 (Shift-I)]

134. An annular disk of mass M, inner radius a and outer radius b is placed on a horizontal surface with coefficient of friction μ, as shown in the figure. At some time, an impulse $J_0\hat{x}$ is applied at a height h above the center of the disk. If $h = h_m$ then the disk rolls without slipping along the x-axis. Which of the following statement(s) is(are) correct?

[JEE Adv, 2023]

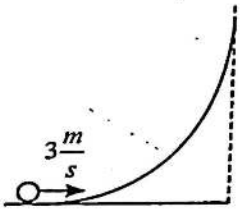


(a) For $\mu \neq 0$ and $a \to 0$, $h_m = b/2$
(b) For $\mu \neq 0$ and $a \to b$, $h_m = b$
(c) For $h = h_m$, the initial angular velocity does not depend on the inner radius a.
(d) For $\mu = 0$ and $h = 0$. the wheel always slides without rolling.

135. A hollow spherical ball of uniform density rolls up a curved surface with an initial velocity 3 m/s (as shown in figure). Maximum height with respect to the initial position covered by it will be _____cm.

[8 April, 2023 (Shift-II)]

(take, $g = 10$ gm/s^2)

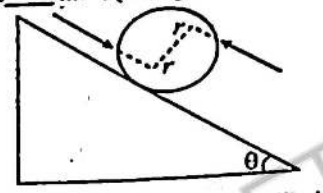


136. A solid cylinder and a solid sphere, having same mass M and radius R, roll down the same inclined plane from top without slipping. They start from rest. The ratio of velocity of the solid cylinder to that of the solid sphere, with which they the ground, will be:

[25 July, 2022 (Shift-I)]

(a) $\frac{\sqrt{5}}{3}$ (b) $\sqrt{\frac{4}{5}}$ (c) $\sqrt{\frac{3}{5}}$ (d) $\sqrt{\frac{14}{15}}$

137. A solid sphere of mass 1 kg and radius 1 m rolls without slipping on a fixed inclined plane with an angle of inclination $\theta = 30°$ from the horizontal. Two forces of magnitude 1 N each, parallel to the incline, act on the sphere, both at distance $r = 0.5$ m from the center of the sphere, as shown in the figure. The acceleration of the sphere down the plane is _____ ms^{-2}. (Take $g = 10$ ms^{-2}.) [JEE Adv, 2021]



138. At time $t = 0$, a disk of radius 1 m starts to roll without slipping on a horizontal plane with an angular acceleration of $\alpha = \frac{2}{3}$ rad s^{-2}. A small stone is stuck to the disk. At $t = 0$, it is at the contact point of the disk and the plane. Later, at time $t = \sqrt{\pi}s$, the stone detaches itself and flies off tangentially from the disk. The maximum height (in m) reached by the stone measured from the plane is $\frac{1}{2} + \frac{x}{10}$. The value of x is [Take $g = 10$ ms^{-2}].

[JEE Adv, 2022]

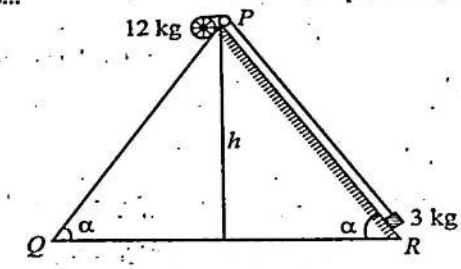
139. A solid spherical ball is rolling on a frictionless horizontal plane surface about its axis of symmetry. The ratio of rotational kinetic energy of the ball to its total kinetic energy is:

[26 June, 2022 (Shift-II)]

(a) 2/5 (b) 2/7 (c) 1/5 (d) 7/10

140. A rolling wheel of 12 kg is on an inclined plane at position P and connected to a mass of 3 kg through a string of fixed length and pulley as shown in figure.
Consider PR as friction free surface.
The velocity of centre of mass of the wheel when it reaches at the bottom Q of the inclined plane PQ will be $\frac{1}{2}\sqrt{xgh}$ m/s. The value of x is...

[27 June, 2022 (Shift-II)]



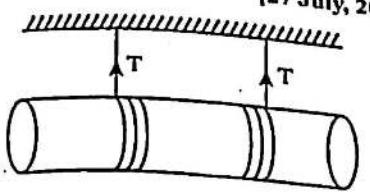
141. A disc of mass 1kg and radius R is free to rotate about a horizontal axis passing through its centre and perpendicular to the plane of disc. A body of same mass as that of disc is fixed at the highest point of the disc. Now the system is released, when the body comes to the lowest position, its angular speed will be $4\sqrt{\frac{x}{3R}}$ radS^{-1} where $x =$ _____.
($g = 10$ ms^{-2})

[26 July, 2022 (Shift-I)]

@TAREEQBSE @RAJDHANET

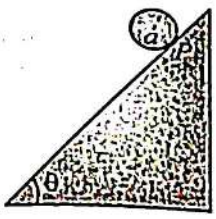
142. A solid cylinder length is suspended symmetrically through two massless strings, as shown in the figure. The distance from the initial rest position, the cylinder should by unbinding the strings to achieve a speed of 4 ms^{-1}, is _____cm. (take $g = 10\ ms^{-2}$)

[27 July, 2022 (Shift-II)]



143. A solid disc of radius 'a' and mass 'm' rolls down without slipping on an inclined plane making an angle θ with the horizontal. The acceleration of the disc will be $\frac{2}{b}g\sin\theta$ where b is (Round off to the Nearest Integer) (g = acceleration due to gravity, θ = angle as shown in figure)

[16 March, 2021 (Shift-II)]



144. A body rolls down an inclined plane without slipping. The kinetic energy of rotation is 50% of its translational kinetic energy. The body is:

[20 July, 2021 (Shift-II)]

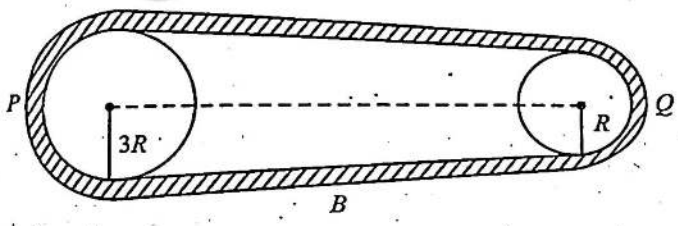
(a) Hollow cylinder (b) Ring
(c) Solid sphere (d) Solid cylinder

145. A 2 kg steel rod of length 0.6 m is clamped on a table vertically at its lower end and is free to rotate in vertical plane. The upper end is pushed so that the rod falls under gravity. Ignoring the friction due to clamping at its lower end, the speed of the free end of rod when it passes through its lowest position is _____ ms^{-1}.

[1 Sept, 2021 (Shift-II)]

146. In the given figure, two wheels P and Q are connected by a belt B. The radius of P is three times as that of Q. In case of same rotational kinetic energy, the ratio of rotational inertias $\frac{I_1}{I_2}$ will be $x:1$. The value of x will be _____.

[27 July, 2021 (Shift-II)]



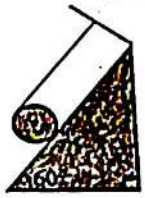
147. A boy is rolling a 0.5 kg ball on the frictionless floor with the speed of 20 ms^{-1}. The ball gets deflected by an obstacle on the way. After deflection it moves with 5% of its initial kinetic energy. What is the speed of the ball now?

[17 March, 2021 (Shift-I)]

(a) 14.41ms^{-1} (b) 19.0 ms^{-1}
(c) 1.00ms^{-1} (d) 4.47 ms^{-1}

148. A solid cylinder of mass m is wrapped with an inextensible light string and, is placed on a rough inclined plane as shown in the figure. The frictional force acting between the cylinder and the inclined plane is:
[The coefficient of static friction, μ, is 0.4]

[18 March, 2021 (Shift-II)]



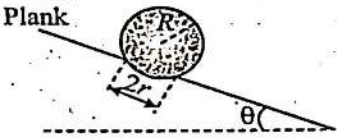
(a) 0 (b) $\frac{7mg}{2}$ (c) 5 mg (d) $\frac{mg}{5}$

149. A rod of mass M and length L is lying on a horizontal frictionless surface. A particle of mass 'm' travelling along the surface hits at one end of the rod with a velocity 'u' in a direction perpendicular to the rod. The collision is completely elastic. After collision, particle comes to rest. The ratio of masses $\left(\frac{m}{M}\right)$ is $\frac{1}{x}$. The value of 'x' will be _____.

[20 July, 2021 (Shift-I)]

150. A football of radius R is kept on a hole of radius r ($r < R$) made on a plank kept horizontally. One end of the plank is now lifted so that it gets tilted making an angle θ from the horizontal as shown in the figure below. The maximum value of θ so that the football does not start rolling down the plank satisfies (figure is schematic and not drawn to scale)

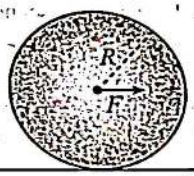
[JEE Adv, 2020]



(a) $\sin\theta = \frac{r}{R}$ (b) $\tan\theta = \frac{r}{R}$ (c) $\sin\theta = \frac{r}{2R}$ (d) $\cos\theta = \frac{r}{2R}$

151. A horizontal force F is applied at the centre of mass of a cylindrical object of mass m and radius, perpendicular to its axis as shown in the figure. The coefficient of friction between the object and the ground is μ. The centre of mass of the object has an acceleration a. The acceleration due to gravity is g. Given that the object rolls without slipping, which of the following statement(s) is(are) correct?

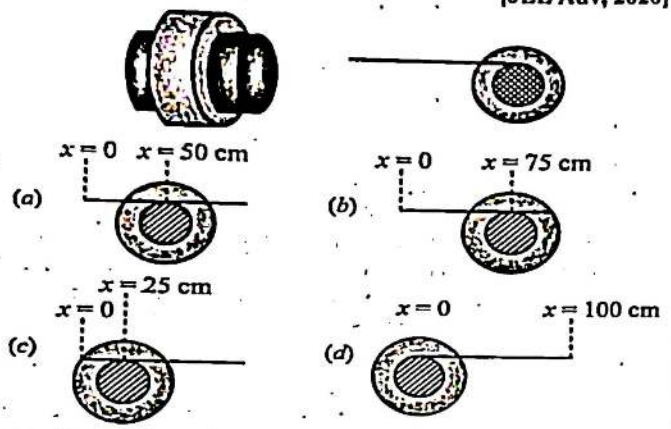
[JEE Adv, 2020]



(a) For the same F, the value of a does not depend on whether the cylinder is solid or hollow
(b) For a solid cylinder, the maximum possible value of a is $2\mu g$
(c) The magnitude of the frictional force on the object due to the ground is always μmg
(d) For a thin-walled hollow cylinder, $a = \frac{F}{2m}$

@FIITJEE

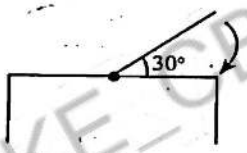
152. A small roller of diameter 20 cm has an axle of diameter 10 cm (see figure below on the left). It is on a horizontal floor and a meter scale is positioned horizontally on its axle with one edge of the scale on top of the axle (see figure on the right). The scale is now pushed slowly on the axle so that it moves without slipping on the axle, and the roller starts rolling without slipping. After the roller has moved 50 cm, the position of the scale will look like (figures are schematic and not drawn to scale) **[JEE Adv, 2020]**



153. A uniform sphere of mass 500 g rolls without slipping on a plane horizontal surface with its centre moving at a speed of 5.00 cm/s. Its kinetic energy is: **[8 Jan, 2020 (Shift-II)]**

(a) 8.75×10^{-4} J (b) 8.75×10^{-3} J
(c) 6.25×10^{-4} J (d) 1.13×10^{-3} J

154. One end of a straight uniform 1 m long bar is pivoted on horizontal table. It is released from rest when it makes an angle 30° from the horizontal (see figure). Its angular speed when it hits the table is given as $\sqrt{n}s^{-1}$, where n is an integer. The value of n is_____. **[9 Jan, 2020 (Shift-I)]**



155. A uniformly thick wheel with moment of inertia I and radius R is free to rotate about its centre of mass (see figure). A massless string is wrapped over its rim and two blocks of masses m_1 and m_2 ($m_1 > m_2$) are attached to the ends of the string. The system is released from rest. The angular speed of the wheel when m_1 descents by a distance h is: **[9 Jan, 2020 (Shift-II)]**

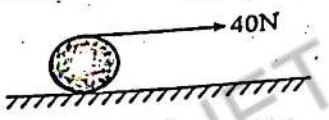
(a) $\left[\frac{m_1+m_2}{(m_1+m_2)R^2+I}\right]^{\frac{1}{2}} gh$ (b) $\left[\frac{2(m_1-m_2)gh}{(m_1+m_2)R^2+I}\right]^{\frac{1}{2}}$

(c) $\left[\frac{2(m_1+m_2)gh}{(m_1+m_2)R^2+I}\right]^{\frac{1}{2}}$ (d) $\left[\frac{(m_1+m_2)}{(m_1+m_2)R^2+I}\right]^{\frac{1}{2}} gh$

156. The following bodies are made to roll up (without slipping) the same inclined plane from a horizontal plane: (*I*) a ring of radius R (*II*) a solid cylinder of radius $\frac{R}{2}$ and (*III*) a solid sphere of radius $\frac{R}{4}$. If in each case, the speed of the centre of mass at bottom of the incline is same, the ratio of the maximum heights they climb is: **[9 April, 2019 (Shift-I)]**

(a) 4 : 3 : 2 (b) 14 : 15 : 20
(c) 10 : 15 : 7 (d) 2 : 3 : 4

157. A string is wound around a hollow cylinder of mass 5 kg and radius 0.5m. If the string is now pulled with a horizontal force of 40 N, and the cylinder is rolling without slipping on a horizontal surface (as in figure), then the angular acceleration of the cylinder will be (Neglect the mass and thickness of the string) **[11 Jan, 2019 (Shift-II)]**



(a) 20 rad/s² (b) 16 rad/s²
(c) 12 rad/s² (d) 10 rad/s²

158. A homogeneous solid cylindrical roller of radius R and mass M is pulled on a cricket pitch by a horizontal force. Assuming rolling without slipping, angular acceleration of the cylinder is : **[10 Jan, 2019 (Shift-I)]**

(a) $\frac{3F}{2mR}$ (b) $\frac{F}{3mR}$
(c) $\frac{F}{2mR}$ (d) $\frac{2F}{3mR}$

159. A solid sphere and solid cylinder of identical radii approach an incline with the same linear velocity (see figure). Both roll without slipping all throughout. The two climb maximum heights h_{sph} and h_{cyl} on the incline. The radio $\frac{h_{sph}}{h_{cyl}}$ is given by: **[8 April, 2019 (Shift-II)]**

(a) 1 (b) $\frac{4}{5}$
(c) $\frac{2}{\sqrt{5}}$ (d) $\frac{14}{15}$

160. Moment of inertia of a body about a given axis is 1.5 kg m². Initially the body is at rest. In order to produce a rotational kinetic energy of 1200 J, the angular acceleration of 20 rad/s² must be applied about the axis of rotation for a duration of: **[9 April, 2019 (Shift-II)]**

(a) 2 s (b) 5 s (c) 2.5 s (d) 3 s

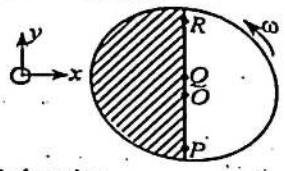
@RAJ_PLANET

JEE-Advanced

Angular Displacement, Velocity and Acceleration

Single Correct

1. Consider a disc rotating in the horizontal plane with a constant angular speed ω about its centre O.



The disc has a shaded region on one side of the diameter and an unshaded region on the other side as shown in the figure. When the disc is in the orientation as shown, two pebbles P and Q are simultaneously projected at an angle towards R. The velocity of projection is in the y-z plane and is same for both pebbles with respect to the disc.

Assume that (*i*) they land back on the disc before the disc has completed 1/8 rotation, (*ii*) their range is less than half the disc radius, and (*iii*) ω remains constant throughout. Then **(IIT-JEE 2012)**

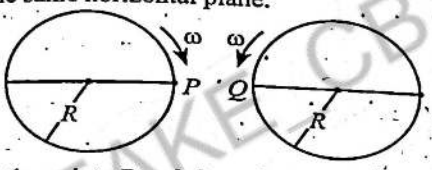
(*a*) P lands in the shaded region and Q in the unshaded region

(*b*) P lands in the unshaded region and Q in the shaded region

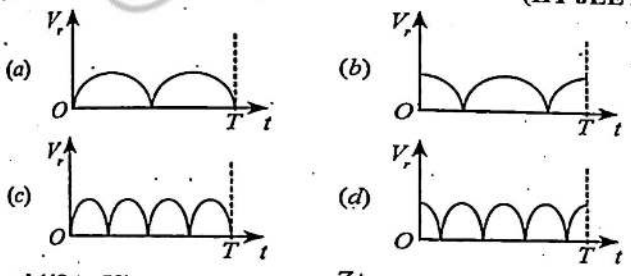
(*c*) both P and Q land in the unshaded region

(*d*) both P and Q land in the shaded region

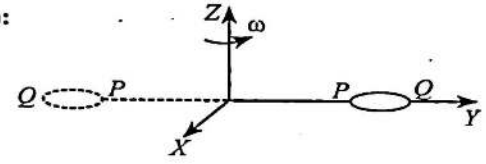
2. Two identical discs of same radius R are rotating about their axes in opposite directions with the same constant angular speed ω. The discs are in the same horizontal plane.



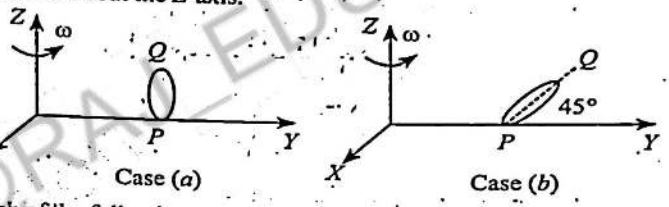
At time $t = 0$, the points P and Q are facing each other as shown in the figure. The relative speed between the two points P and Q is v_r. In one time period (T) of rotation of the discs, v_r as a function of time is best represented by **(IIT-JEE 2012)**



Paragraph(48 to 50):



The general motion of a rigid body can be considered to be a combination of (*I*) a motion of its center of mass about an axis, and (*II*) its motion about an instantaneous axis passing through the centre of mass. These axes need not be stationary. Consider, for example, a thin uniform disc welded (rigidly fixed) horizontally at its rim to a massless stick, as shown in the figure. When the disc-stick system is rotated about the origin on a horizontal frictionless plane with angular speed ω, the motion at any instant can be taken as a combination of (*I*) a rotation of the centre of mass of the disc about the Z-axis, and (*II*) a rotation of the disc through an instantaneous vertical axis passing through its centre of mass (as is seen from the changed orientation of points P and Q). Both these motions have the same angular speed ω in this case. Now, consider two similar systems as shown in the figure : Case (*a*) the disc with its face vertical and parallel to x-z plane; Case (*b*) the disc with its face making an angle of 45° with x-y plane and its horizontal diameter parallel to X-axis. In both the cases, the disc is welded at point P, and the systems are rotated with constant angular speed ω about the Z-axis.



3. Which of the following statements regarding the angular speed about the instantaneous axis (passing through the centre of mass) is correct? **(IIT-JEE 2012)**

(*a*) It is $\sqrt{2}\ \omega$ for both the cases

(*b*) It is ω for case (*a*); and $\omega/\sqrt{2}$ for case (*b*)

(*c*) It is ω for case (*a*); and $\sqrt{2}\ \omega$ for case (*b*)

(*d*) It is ω for both the cases

4. A particle moves in a circular path with decreasing speed. Choose the correct statement **(IIT-JEE 2005)**

(*a*) Angular momentum remains constant

(*b*) Acceleration (a) is towards the centre

(*c*) Particle moves in a spiral path with decreasing radius

(*d*) The direction of angular momentum remains constant

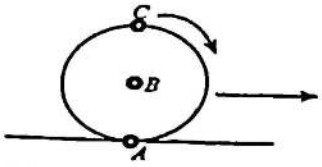
5. A smooth sphere A is moving on a frictionless horizontal plane with angular velocity ω and center of mass velocity v. It collides elastically and heads on with an identical sphere B at rest. Neglect friction everywhere. After the collision their angular speeds are ω_A and ω_B respectively. Then, **(IIT-JEE 1999)**

(*a*) $\omega_A < \omega_B$ (*b*) $\omega_A = \omega_B$ (*c*) $\omega_A = \omega$ (*d*) $\omega_B = \omega$

Multiple Correct

6. Sphere is rolling without slipping on a fixed horizontal plane surface. In the figure, A is the point of contact, B is the centre of the sphere and C is its topmost point. Then, **(IIT-JEE 2009)**

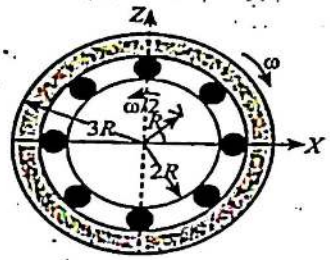
TAKE CBSE X @RAJEDUCATE



(a) $\vec{V}_C - \vec{V}_A = 2(\vec{V}_C - \vec{V}_B)$ (b) $\vec{V}_C - \vec{V}_B = (\vec{V}_B - \vec{V}_A)$

(c) $|\vec{V}_C - \vec{V}_A| = 2|\vec{V}_C - \vec{V}_B|$ (d) $\vec{V}_C - \vec{V}_A = 4|\vec{V}_B|$

7. The figure shows a system consisting of (*i*) a ring of outer radius $3R$ rolling clockwise without slipping on a horizontal surface with angular speed ω and (*ii*) an inner disc of radius $2R$ rotating anti-clockwise with angular speed $\omega/2$ The ring and disc are separated by frictionless ball bearings. The system is in the x-z plane. The point P on the inner disc is at a distance R from the origin, where OP makes an angle of 30° with the horizontal. Then with respect to the horizontal surface, **(IIT-JEE 2012)**



(a) the point O has a linear velocity $3R\omega\hat{i}$

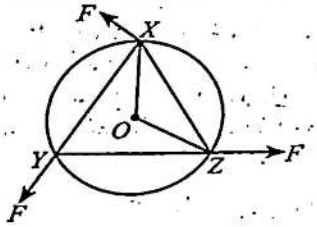
(b) the point P has a linear velocity $\frac{11}{4}R\omega\hat{i} + \frac{\sqrt{3}}{4}R\omega\hat{k}$

(c) the point P has a linear velocity $\frac{13}{4}R\omega\hat{i} - \frac{\sqrt{3}}{4}R\omega\hat{k}$

(d) the point P has a linear velocity $\frac{1}{4}R\omega\hat{i} + \left(3 - \frac{\sqrt{3}}{4}\right)R\omega\hat{k}$

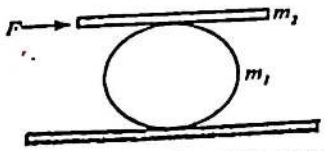
Numerical Types/Integer Types

8. A uniform circular disc of mass 1.5kg and radius 0.5m is initially at rest on a horizontal frictionless surface. Three forces of equal magnitude $F = 0.5N$ are applied simultaneously along the three sides of an equilateral triangle $FXYZ$ with its vertices on the perimeter of the disc (see figure). One second after applying the forces, the angular speed of the disc in rad s^{-1} is **(IIT-JEE 2012)**



Subjective

9. A man pushes a cylinder of mass m_1 with the help of a plank of mass m_2 as shown. There is no slipping at any contact. The horizontal component of the force applied by the man is F. Find



(a) the accelerations of the plank and the centre of mass of the cylinder and

(b) the magnitudes and directions of frictional forces at contact points. **(IIT-JEE 199**

Fill in the Blanks

10. A uniform disc of mass m and radius R is rolling up a rough inclined plane which makes an angle of 30° with the horizontal. If the coefficients of static and kinetic friction are each equal to μ and the only forces acting are gravitational and frictional, then the magnitude of the frictional force acting on the disc is ..... and its direction is (write up or down) the inclined plane. **(IIT-JEE 199**

11. A smooth uniform rod of length L and mass M has two identical beads of negligible size, each of mass m, which can slide freely along the rod. Initially, the two beads are at the centre of the rod and the system is rotating with an angular velocity ω_0 about an axis perpendicular to the rod and passing through the midpoint of the rod (see figure).

There are no external forces. When the beads reach the ends of the rod, the angular velocity of the system is..... **(IIT-JEE 198**

True/False

12. A thin uniform circular disc of mass M and radius R is rotating in a horizontal plane about an axis passing through its centre and perpendicular to its plane with an angular velocity ω. Another disc of the same dimensions but of mass $M/4$ is placed gently on the first disc coaxially. The angular velocity of the system now is $2\omega/5$ **(JEE Adv. 198**

Moment of Inertia

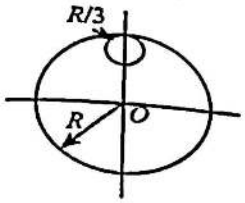
Single Correct

13. A solid sphere of radius R has moment of inertia I about its geometrical axis. It is melted into a disc of radius r and thickness t. If it's moment of inertia about the tangential axis (which is perpendicular to plane of the disc) is also equal to I, then the value of r is equal to **(IIT-JEE 200**

(a) $\frac{2}{\sqrt{15}}R$ (b) $\frac{2}{\sqrt{5}}R$ (c) $\frac{3}{\sqrt{15}}R$ (d) $\frac{\sqrt{3}}{\sqrt{15}}R$

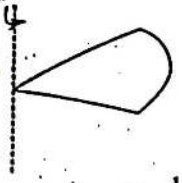
@IITJEE_SBGE_X @RAJ_EDUCATION

14. A circular disc of radius R and mass $9M$, a small disc of radius $R/3$ is removed from the disc. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through O is **(IIT-JEE 2005)**



(a) $4MR^2$ (b) $\frac{40}{9}MR^2$ (c) $10MR^2$ (d) $\frac{37}{9}MR^2$

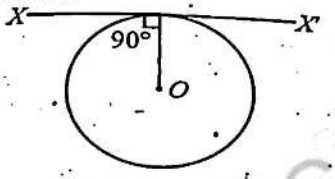
15. One quarter section is cut from a uniform circular disc of radius R. This section has a mass M. It is made to rotate about a line perpendicular to its plane and passing through the center of the original disc. Its moment of inertia about the axis of rotation is



(IIT-JEE 2001)

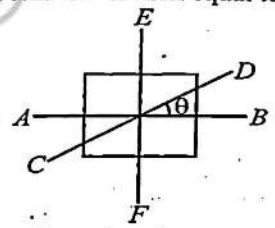
(a) $\frac{1}{2}MR^2$ (b) $\frac{1}{4}MR^2$ (c) $\frac{1}{8}MR^2$ (d) $\sqrt{2}MR^2$

16. A thin wire of length l, and uniform linear mass density ρ bent into a circular loop with centre at as shown. The moment of inertia of the loop about the axis is **(IIT-JEE 2000)**



(a) $\frac{\rho l^3}{8\pi^2}$ (b) $\frac{\rho l^3}{16\pi^2}$ (c) $\frac{5\rho l^3}{16\pi^2}$ (d) $\frac{3\rho l^3}{8\pi^2}$

17. Let I be the moment of inertia of a uniform square plate about an axis AB that passes through its centre and is parallel to two of its sides. CD is a line in the plane of the plate that passes through the centre of the plate and makes an angle θ with AB. The moment of inertia of the plate about the axis CD is then equal to **(IIT-JEE 1998)**



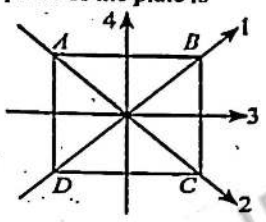
(a) I (b) $I\sin^2\theta$
(c) $I\cos^2\theta$ (d) $I\cos^2(\theta/2)$

18. Two point masses of 0.3kg and 0.7kg are fixed at the ends of a rod of length 1.4m and of negligible mass. The rod is set rotating about an axis perpendicular to its length with a uniform angular speed. The point on the rod through which the axis should pass in order that the work required for rotation of the rod is minimum, is located at a distance of **(IIT-JEE 1992)**

(a) 0.42m from mass of 0.3 kg
(b) 0.70m from mass of 0.7 kg
(c) 0.98m from mass of 0.3 kg
(d) 0.98m from mass of 0.7 kg

Multiple Correct

19. The moment of inertia of a thin square plate $ABCD$, of uniform thickness about an axis passing through the centre O and perpendicular to the plane of the plate is

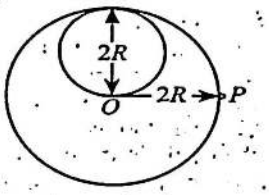


where, I_1, I_2, I_3 and I_4 are respectively moments of inertia about axes 1, 2, 3 and 4 which are in the plane of the plate **(IIT-JEE 1992)**

(a) $I_1 + I_2$ (b) $I_3 + I_4$
(c) $I_1 + I_3$ (d) $I_1 + I_2 + I_3 + I_4$

Numerical Types/Integer Types

20. A lamina is made by removing a small disc of diameter $2R$ from a bigger disc of uniform mass density and radius $2R$, as shown in the figure. The moment of inertia of this lamina about axes passing through O and P is I_O and I_P, respectively. Both these axes are perpendicular to the plane of the lamina. The ratio I_P/I_O to the nearest integer is **(IIT-JEE 2012)**



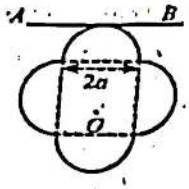
21. Four solid spheres each of diameter $\sqrt{5}$ cm and mass 0.5 kg are placed with their centres at the comers of a square of side 4 cm. The moment of inertia of the system about the diagonal of the square is $N\times10^{-4}$ kg-m^2, then N is **(IIT-JEE 2011)**

Fill in the Blanks

22. Put a uniform meter scale horizontally on your extended index fingers with the left one at 0.00 cm and the right one at 90.00 cm. When you attempt to move both the fingers slowly towards the center, initially only the left finger slips with respect to the scale and the right finger does not. After some distance the left finger stops and the right one starts slipping. Then the right finger stops at a distance x_R from the center (50.00 cm) of the scale and the let one starts slipping again. This happens because of the difference in the frictional forces on the two fingers. If the coefficients of static and dynamic friction between the fingers and the scale are 0.40 and 0.32, respectively, the value of x_R (in cm) is _____ **(JEE Adv. 2020)**

@TAKE_CBSE_X_@RAJ_EDUNET

23. A symmetric lamina of mass M consists of a square shape with a semi-circular section over of the edge of the square as shown in figure. The side of the square is $2a$. The moment of inertia of the lamina about an axis through its centre of mass and perpendicular to the plane is $1.6\,Ma^2$. The moment of inertia of the lamina about the tangent AB in the plane of the lamina is ..... (IIT-JEE 1997)



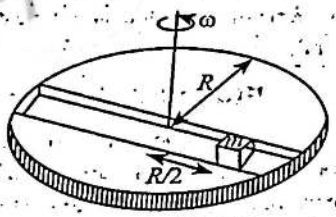
Subjective

24. A rod of length L and mass M is hinged at point O. A small bullet of mass m hits the rod as shown in the figure. The bullet gets embedded in the rod. Find angular velocity of the system just after impact. (IIT-JEE 2005)

Torque and its Applications

Single Correct

25. A frame of the reference that is accelerated with respect to an inertial frame of reference is called a non-inertial frame of reference. A coordinate system fixed on a circular disc rotating about a fixed axis with a constant angular velocity ω is an example of a non-inertial frame of reference. The relationship between the force F_{rot} experienced by a particle of mass m moving on the rotating disc and the force Fin experienced by the particle in an inertial frame of reference is, $F_{rot} = F_{in} + 2m(v_{rot} \times \omega) + m(\omega \times r) \times \omega$, where, v_{rot} is the velocity of the particle in the rotating frame of reference and r is the position vector of the particle with respect to the centre of the disc. Now, consider a smooth slot along a diameter of a disc of radius R rotating counter-clockwise with a constant angular speed ω about its vertical axis through its centre. We assign a coordinate system with the origin at the centre of the disc, the X-axis along the slot, the Y-axis perpendicular to the slot and the z-axis along the rotation axis ($\omega = \omega k$). A small block of mass m is gently placed in the slot at $r = (R/2)\,\hat{i}$ at $t = 0$ and is constrained to move only along the slot.



The net reaction of the disc on the block is

C-26.79 W-70.81 UA-2.4 (JEE Adv. 2016)

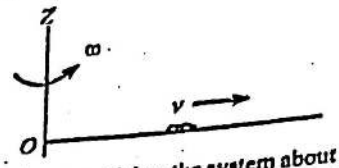
(a) $m\omega^2 R\sin\omega\hat{j} - mg\hat{k}$

(b) $\frac{mR\omega^2}{2}\left[e^{\omega t} - e^{-\omega t}\right]\hat{j} + mg\hat{k}$

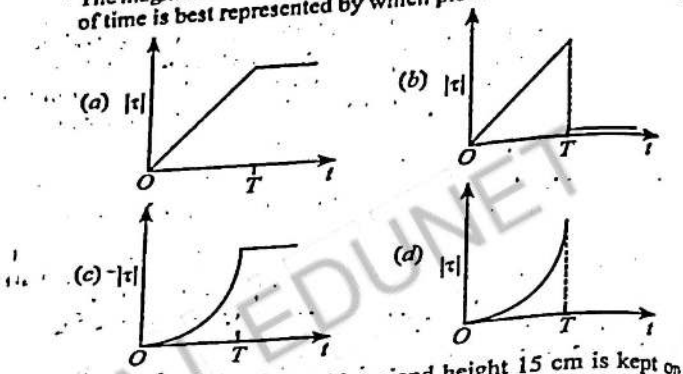
(c) $\frac{mR\omega^2}{2}\left[e^{2\omega t}e^{-2\omega t}\right]\hat{j} + mg\hat{k}$

(d) $-m\omega^2 R\sin\omega\hat{j} - mg\hat{k}$

26. A thin uniform rod, pivoted at O, is rotating in the horizontal pl with constant angular speed ω, as shown in the figure. At time t a small insect starts from O and moves with constant speed v respect to the rod towards the other end. It reaches the end of rod at $t = T$ and stops. The angular speed of the system remains throughout.



The magnitude of the torque $|\tau|$ on the system about O, as a funct of time is best represented by which plot? (IIT-JEE 201



27. A block of base 10 cm × 10 cm and height 15 cm is kept on inclined plane. The coefficient of friction between them is $\sqrt{3}$. The inclination θ of this inclined plane from the horizontal plane gradually increased from 0°. Then, (IIT-JEE 200

(a) at θ = 30°, the block will start sliding down the plane

(b) the block will remain at rest on the plane up to certain θ and then it will topple

(c) at θ = 60°, the block will start sliding down the plane and continue to do so at higher angles.

(d) at θ = 60°, the block will start sliding down the plane and further increasing θ, it will topple at certain θ

28. A particle undergoes uniform circular motion. About which poin on the plane of the circle, will the angular momentum of the partic remain conserved? (IIT-JEE 200

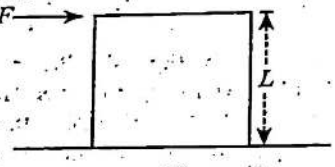
(a) Centre of circle

(b) On the circumference of the circle

(c) Inside the circle

(d) Outside the circle

29. A cubical block of side L rests on a rough horizontal surface wi coefficient of friction μ. A horizontal force F is applied on the bloc as shown. If the coefficient of friction is sufficiently high, so that th block does not slide before toppling, the minimum force require to topple the block is (IIT-JEE 200



(a) Infinitesimal (b) $mg/4$

(c) $mg/2$ (d) $mg(1-\mu)$

@MTG_PHYSICS @MTGEDUNET

Multiple Correct

30. A particle of mass $M = 0.2$ kg is initially at rest in the xy-plane at a point $(x = -l, y = -h)$ where $l = 10$ m and $h = 1$ m. The particle is accelerated at time $t = 0$ with a constant acceleration $a = 10$ m/s² along the positive x-direction. Its angular momentum and torque with respect to the origin, in SI units, are represented by $\vec{L}$ and $\vec{\tau}$, respectively. $\hat{i}, \hat{j}$ and $\hat{k}$ are unit vectors along the positive x, y and z-directions, respectively. If $\hat{k} = \hat{i} \times \hat{j}$ then which of the following statement(s) is(are) correct?

C-18.94 W-11.64 UA-42.06 PC-27.37 (JEE Adv. 2021)

(a) The particle arrives at the point $(x = l, y = -h)$ at time $t = 2$s

(b) $\vec{\tau} = 2\hat{k}$ when the particle passes through the point $(x = l, y = -h)$

(c) $\vec{L} = 4\hat{k}$ when the particle passes through the point $(x = l, y = -h)$

(d) $\vec{\tau} = \hat{k}$ when the particle passes through the point $(x = 0, y = -h)$

31. Consider a body of mass 1.0 kg at rest at the origin at time $t = 0$. A force $\vec{F} = (\alpha t\hat{i} + \beta\hat{j})$ is applied on the body, where $\alpha = 1.0\text{Ns}^{-1}$ and $\beta = 1.0$N. The torque acting on the body about the origin at time $\tau = 1.0$s is τ. Which of the following statements is (are) true? **C-16.3 W-41.89 UA-27.15 PC-14.67 (JEE Adv. 2018)**

(a) $|\vec{\tau}| = 1/3$ N-m

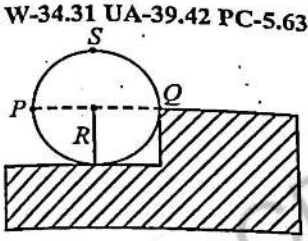
(b) The torque $\vec{\tau}$ is in the direction of the unit vector $+\hat{k}$

(c) The velocity of the body at $t = 1$s is $\vec{v} = 1/2\,(\hat{i} + 2\hat{j})$ ms^{-1}

(d) The magnitude of displacement of the body at $t = 1$s is 1/6 m

32. A wheel of radius R and mass M is placed at the bottom of a fixed step of height R as shown in the figure. A constant force is continuously applied on the surface of the wheel so that it just climbs the step without slipping. Consider the torque τ about an axis normal to the plane of the paper passing through the point Q. Which of the following options is/are correct?

C-20.63 W-34.31 UA-39.42 PC-5.63 (JEE Adv. 2017)



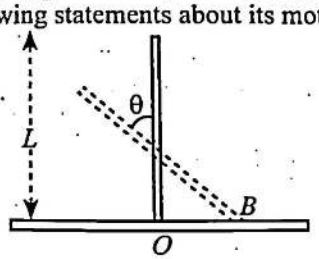
(a) If the force is applied to the circumference at point P, then τ_{net} is zero

(b) If the force is applied tangentially at point S, then $\tau_{net} \neq 0$ but the wheel never climbs the step

(c) If the force is applied at point P tangentially, then τ_{net} decreases continuously as the wheel climbs

(d) If the force is applied normal to the circumference at point X, then τ_{net} is constant

33. A rigid uniform bar AB of length L is slipping from its vertical position on a frictionless floor (as shown in the figure). At some instant of time, the angle made by the bar with the vertical is θ. Which of the following statements about its motion is/are correct?



C-9.75 W-29.75 UA-28.15 PC-32.35 (JEE Adv. 2017)

(a) Instantaneous torque about the point in contact with the floor is proportional to $\sin\theta$

(b) The trajectory of the point A is parabola

(c) The mid-point of the bar will fall vertically downward

(d) When the bar makes an angle θ with the vertical, the displacement of its mid-point from the initial position is proportional to $(1 - \cos\theta)$

34. The torque τ on a body about a given point is found to be equal to $A \times L$, where A is a constant vector and L is the angular momentum of the body about that point. From this it follows that **(IIT-JEE 1998)**

(a) dL/dt is perpendicular to L at all instants of time

(b) The component of L in the direction of A does not change with time

(c) The magnitude of L does not change with time

(d) L does not change with time

Match the Column

35. In the List-I below, four different paths of a particle are given as functions of time. In these functions, α and β are positive constants of appropriate dimensions and $\alpha \neq \beta$. In each case, the force acting on the particle is either zero or conservative. In List-II, five physical quantities of the particle are mentioned: p is the linear momentum, L is the angular momentum about the origin, K is the kinetic energy, U is the potential energy and E is the total energy. Match each path in List-I with those quantities in List-II, which are conserved for that path. **C-27.33 W-34.48 UA-38.19 (JEE Adv. 2018)**

List-I		List-II	
P	$r(t) = \alpha t i + \beta t j$	1.	P
Q	$r(t) = \alpha\cos\omega t i + \beta\sin\omega t j$	2.	L
R	$r(t) = \alpha(\cos\omega t i + \sin\omega t j)$	3.	K
S	$r(t) = \alpha t i + \beta/2t^2 j$	4.	U
		5.	E

(a) P → 1, 2, 3, 4, 5; Q → 2, 5; R → 2, 3, 4, 5; S → 5

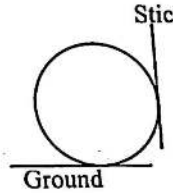
(b) P → 1, 2, 3, 4, 5; Q → 3, 5; R → 2, 3, 4, 5; S → 2, 5

(c) P → 2, 3, 4; Q → 5; R → 1, 2, 4; S → 2, 5

(d) P → 1, 2, 3, 5; Q → 2, 5; R → 2, 3, 4, 5; S → 2, 5

Numerical Types/Integer Types

36. A boy is pushing a ring of mass 2 kg and radius 0.5 m with a stick as shown in the figure. The stick applies a force of $2N$ on the ring and rolls it without slipping with an acceleration of 0.3 m/s². The coefficient of friction between the ground and the ring is large enough that rolling always occurs and the coefficient of friction between the stick and the ring is $(P/10)$. The value of P is

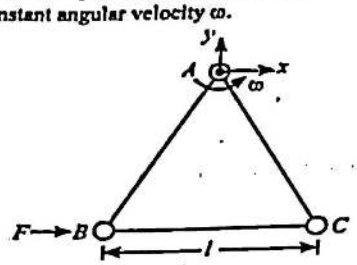


(IIT-JEE 2011)

@FAKE_CBSE_Y@RAJIVSIR.NET

Subjective

37. Three particles A, B and C, each of mass m, are connected to each other by three massless rigid rods to form a rigid, equilateral triangular body of side l. This body is placed on a horizontal frictionless table (x-y plane) and is hinged to it at the point A, so that it can move without friction about the vertical axis through A (see figure). The body is set into rotational motion on the table about A with a constant angular velocity ω.



(a) Find the magnitude of the horizontal force exerted by the hinge on the body.

(b) At time T, when the side BC is parallel to the X-axis, a force F is applied on B along BC (as shown). Obtain the x-component and the y-component of the force exerted by the hinge on the body, immediately after time T. **(IIT-JEE 2005)**

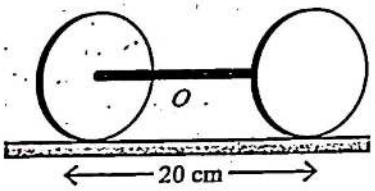
38. A rod AB of mass M and length L is lying on a horizontal frictionless surface. A particle of mass m travelling along the surface hits the end A of the rod with a velocity v_0 in a direction perpendicular to AB. The collision is elastic. After the collision, the particle comes to rest. (2000)

(a) Find the ratio m/M.

(b) A point P on the rod is at rest immediately after collision. Find the distance AP.

(c) Find the linear speed of the point P a time $\pi L/3v_0$ after the collision. **(IIT-JEE 2000)**

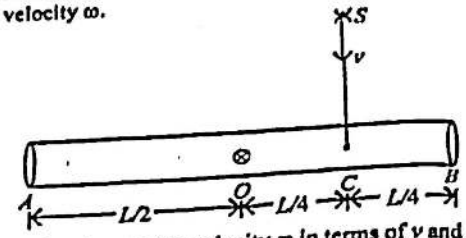
39. Two thin circular discs of mass 2 kg and radius 10 cm each are joined by a rigid massless rod of length 20 cm. The axis of the rod is along the perpendicular to the planes of the disc through their centres. This object is kept on a truck in such a way that the axis of the object is horizontal and perpendicular to the direction of motion of the truck. Its friction with the floor of the truck is large enough, so that the object can roll on the truck without slipping. Take X-axis as the direction of motion of the truck and Z-axis as the vertically upwards direction. If the truck has an acceleration $9 m/s^2$, calculate



(a) the force of friction on each disc and

(b) the magnitude and direction of the frictional torque acting on each disc about the centre of mass O of the object. Express the torque in the vector form in terms of unit vectors $\hat{i}, \hat{j}$ and $\hat{k}$ in x, y and z-directions. **(IIT-JEE 1997)**

40. A homogeneous rod AB of length $L = 1.8$m and mass M is pivoted at the centre O in such a way that it can rotate freely in the vertical plane (figure).
The rod is initially in the horizontal position. An insect S of the same mass M falls vertically with speed v on the point C, midway between the points O and B. Immediately after falling, the insect moves towards the end B such that the rod rotates with a constant angular velocity ω.



(a) Determine the angular velocity ω in terms of v and L

(b) If the insect reaches the end B when the rod has turned through an angle of 90°, determine v. **(IIT-JEE 1997)**

41. A cylinder of mass M and radius R is resting on a horizontal platform (which is parallel to the x-y plane) with its axis fixed along the Y-axis and free to rotate about its axis. The platform is given a motion in the x-direction given by $x = A\cos(\omega t)$. There is no slipping between the cylinder and platform. The maximum torque acting on the cylinder during its motion is **(IIT-JEE 1998)**

42. A uniform cube of side a and mass m rests on a rough horizontal table. A horizontal force F is applied normally to one of the faces at a point that is directly above the center of the face, at a height $3a/4$ above the base. The minimum value of F for which the cube begins to tip about the edge is. (Assume that the cube does not slide). **(IIT-JEE 1984)**

Fill in the Blanks

43. A rod of weight W is supported by two parallel knife edges A and B and is in equilibrium in horizontal position. The knives are at a distance d from each other. The centre of mass of the rod is at a distance x from A. The normal reaction on A is ..... and on B is ..... **(IIT-JEE 1997)**

Angular Momentum and Conservation of Angular Momentum

Single Correct

44. A bar of mas $M = 1.00$ kg and length $L = 0.20$ m is lying on a horizontal frictionless surface. One end of the bar is pivoted at a point about which it is free to rotate. A small mass $m = 0.10$ kg is moving on the same horizontal surface with 5.00 m/s speed on a path perpendicular to the bar. It hits the bar at a distance $L/2$ from the pivoted end and returns back on the same path with speed v. After this elastic collision, the bar rotates with an angular velocity ω. Which of the following statement is correct?

C-10.89 W-29.13 UA-59.98 (JEE Adv. 2013)

(a) $\omega = 6.98$ rad s^{-1} and $v = 4.30$ m s^{-1}

(b) $\omega = 3.75$ rad s^{-1} and $v = 4.30$ m s^{-1}

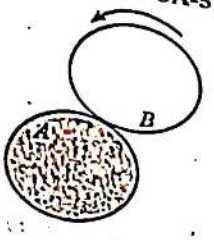
(c) $\omega = 3.75$ rad s^{-1} and $v = 10.0$ m s^{-1}

(d) $\omega = 6.80$ rad s^{-1} and $v = 4.10$ m s^{-1}

@MKE_CBSE_X@YAHOO.COM

45. A flat surface of a thin uniform disk A of radius R is glued to a horizontal table. Another thin uniform disk B of mass M and with the same radius R rolls without slipping on the circumference of A, as shown in the figure. A flat surface of B also lies on the plane of the table. The center of mass of B has fixed angular speed ω about the vertical axis passing through the center of A. The angular momentum of B is $nM\omega R^2$ with respect to the center of A. Which of the following is the value of n?

C-7.25 W-41.53 UA-51.22 (JEE Adv. 2022)



(a) 2 (b) 5 (c) 7/2 (d) 9/2

46. One twirls a circular ring (of mass M and radius R) near the tip of one's finger as shown in Figure 1. In the process the finger never loses contact with the inner rim of the ring. The finger traces out the surface of a cone, shown by the dotted line. The radius of the path traced out by the point where the ring and the finger is in contact is r. The finger rotates with an angular velocity. The rotating ring rolls without slipping on the outside of a smaller circle described by the point where the ring and the finger is in contact (Figure 2). The coefficient of friction between the ring and the finger is μ and the acceleration due to gravity is g.

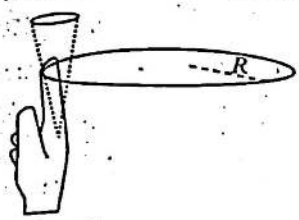


Figure 1

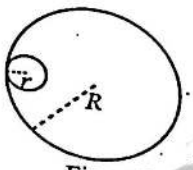


Figure 2

The minimum value of ω_0 below which the ring will drop down is

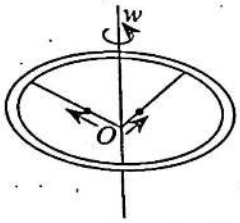
C-24.78 W-71.4 UA-3.82 (JEE Adv. 2017)

(a) $\sqrt{\frac{g}{2\mu(R-r)}}$ (b) $\sqrt{\frac{3g}{2\mu(R-r)}}$

(c) $\sqrt{\frac{g}{\mu(R-r)}}$ (d) $\sqrt{\frac{2g}{\mu(R-r)}}$

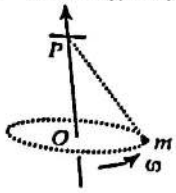
47. A ring of mass M and radius R is rotating with angular speed ω about a fixed vertical axis passing through its center O with two point masses each of mass $M/8$ at rest at O. These masses can move radially outwards along two massless rods fixed on the ring as shown in the figure.

(JEE Adv. 2015)



(a) $\frac{2}{3}R$ (b) $\frac{1}{3}R$ (c) $\frac{3}{5}R$ (d) $\frac{4}{5}R$

48. A small mass m is attached to a massless string whose other end is fixed at P as shown in the figure. The mass is undergoing circular motion in the x-y plane with centre at O and constant angular speed ω. If the angular momentum of the system, calculated about O and P are denoted by L_O and L_P respectively, then **(IIT-JEE 2012)**

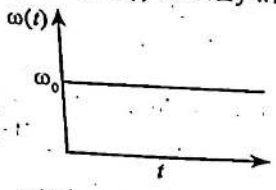


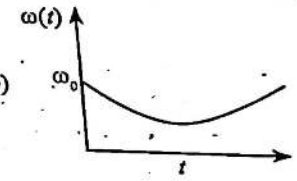
(a) L_O and L_P do not vary with time
(b) L_O varies with time while L_P remains constant
(c) L_O remains constant while L_P varies with time
(d) L_O and L_P both vary with time

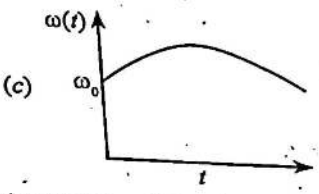
49. Consider a body, shown in figure, consisting of two identical balls, each of mass M connected by a light rigid rod. If an impulse $J = Mv$ is imparted to the body at one of its end, what would be its angular velocity? **(IIT-JEE 2003)**

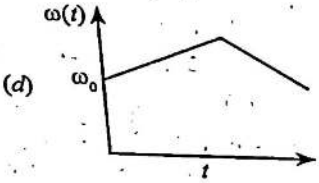
(a) $\frac{V}{L}$ (b) $\frac{2V}{L}$ (c) $\frac{V}{3L}$ (d) $\frac{V}{4L}$

50. A circular platform is free to rotate in a horizontal plane about a vertical axis passing through its centre. A tortoise is sitting at the edge of the platform. Now, the platform is given an angular velocity ω_0. When the tortoise moves along a chord of the platform with a constant velocity (with respect to the platform). The angular velocity of the platform $\omega(t)$ will vary with time t as **(IIT-JEE 2002)**

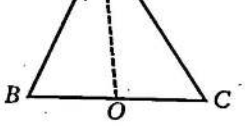
(a) 

(b) 

(c) 

(d) 

51. An equilateral triangle ABC formed from a uniform wire has two small identical beads initially located at A. The triangle is set rotating about the vertical axis AO. Then the beads are released from rest simultaneously and allowed to slide down, one along AB and other along AC as shown.



@FAKE_CBSE_X_@RAJ_EDUNET

Neglecting frictional effects, the quantities that are conserved as beads slides down are (IIT-JEE 2000)

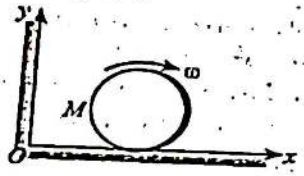
(a) angular velocity and total energy (kinetic and potential)

(b) total angular momentum and total energy

(c) angular velocity and moment of inertia about the axis of rotation

(d) total angular momentum and moment of inertia about the axis of rotation

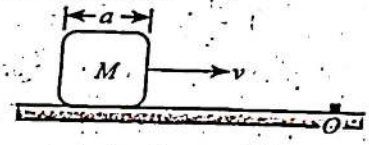
52. A disc of mass M and radius R is rolling with angular speed ω on a horizontal plane as shown. The magnitude of angular momentum of the disc about the origin O is (IIT-JEE 1999)



(a) $\frac{1}{2}MR^2\omega$ (b) $MR^2\omega$

(c) $\frac{3}{2}MR^2\omega$ (d) $2MR^2\omega$

53. A cubical block of side a moving with velocity v on a horizontal smooth plane as shown. It hits a ridge at point O. The angular speed of the block after it hits O is (IIT-JEE 1999)



(a) $\frac{3v}{4a}$ (b) $\frac{3v}{2a}$

(c) $\frac{\sqrt{3}v}{\sqrt{2}a}$ (d) Zero

54. A mass m is moving with a constant velocity along a line parallel to the X-axis, away from the origin. Its angular momentum with respect to the origin (IIT-JEE 1997)

(a) Is zero

(b) Remains constant

(c) Goes on increasing

(d) Goes on decreasing

55. A particle of mass m is projected with a velocity v making an angle of 45° with the horizontal. The magnitude of the angular momentum of the projectile about the point of projection when the particle is at its maximum height h is (IIT-JEE 1990)

(a) 0 (b) $\frac{mv^3}{4\sqrt{2g}}$ (c) $\frac{mv^3}{\sqrt{2g}}$ (d) $m\sqrt{2gh^3}$

56. A particle is projected at time $t=0$ from a point P on the ground with a speed v_0, at an angle of 45° to the horizontal. Find the magnitude and direction of the angular momentum of the particle about P at time $t=v_0/g$. (IIT-JEE 1984)

(a) $\frac{mv_0^3}{2\sqrt{2g}}$ (b) $\frac{mv_0^2}{2\sqrt{2g}}$ (c) $\frac{mv_0^3}{\sqrt{2g}}$ (d) $\frac{mv_0^2}{\sqrt{2g}}$

57. A thin circular ring of mass M and radius r is rotating about its ax with a constant angular velocity ω. Two objects, each of mass are attached gently to the opposite ends of a diameter of the rin The wheel now rotates with an angular velocity (IIT-JEE 19

(a) $\frac{M\omega}{M+m}$ (b) $\frac{(M-2m)\omega}{M+2m}$

(c) $\frac{M\omega}{M+2m}$ (d) $\frac{(M+2m)\omega}{M}$

Multiple Correct

58. A rod of mass m and length L, pivoted at one of its ends, hanging vertically. A bullet of the same mass moving at speed strikes the rod horizontally at a distance x from its pivoted en and gets embedded in it. The combined system now rotates wi angular speed ω about the pivot. The maximum angular speed is achieved for $x = x_M$. Then

C-27.04 W-10.35 UA-37.56 PC-25.05 (JEE Adv. 202

(a) $\omega=\frac{3vx}{L^2+3x^2}$ (b) $\omega=\frac{12vx}{L^2+12x^2}$

(c) $x_M=\frac{L}{\sqrt{3}}$ (d) $\omega_M=\frac{v}{2L}\sqrt{3}$

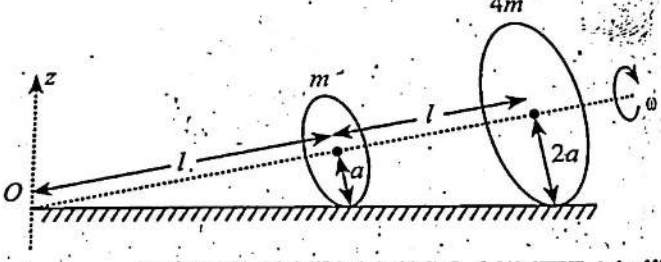
59. The potential energy of mass m at a distance r from a fixed point is given by $V(r)=kr^2/2$, where k is a positive constant of appropri dimensions. This particle is moving in a circular orbit of radi R about the point O. If v is the speed of the particle and L is th magnitude of its angular momentum about O, which of the follow statements is (are) true?

C-36.45 W-32.95 UA-24.82 PC-5.78 (JEE Adv. 201

(a) $v=\sqrt{\frac{k}{2m}}R$ (b) $v=\sqrt{\frac{k}{m}}R$

(c) $L=\sqrt{mk}R^2$ (d) $L=\sqrt{\frac{mk}{2}}R^2$

60. Two thin circular discs of mass m and 4m, having radii of a and $2a$, respectively, are rigidly fixed by a massless, rigid rod of leng $l=\sqrt{24}a$ through their centers. This assembly is laid on a fir and flat surface and set rolling without slipping on the surface s that the angular speed about the axis of the rod is ω. The angul momentum of the entire assembly about the point O' is L (see th figure). Which of the following statement(s) is (are) true?



C-6.21 W-14.3 UA-73.43 PC-6.07 (JEE Adv. 201

BREAK_CBSE X @BALEDUNET

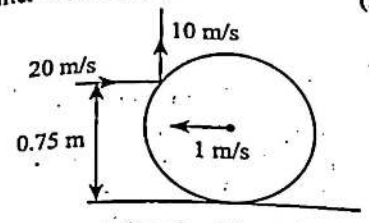
(a) The magnitude of the z-component of L is $55ma^2\omega$

(b) The magnitude of angular momentum of centre of mass of the assembly about the point O is $81ma^2\omega$

(c) The centre of mass of the assembly rotates about the Z-axis with an angular speed of $\frac{\omega}{5}$

(d) The magnitude of angular momentum of the assembly about its centre of mass is $\frac{17ma^2\omega}{2}$

61. A thin ring of mass 2kg and radius 0.5m is rolling without slipping on a horizontal plane with velocity 1m/s. A small ball of mass 0.1 kg, moving with velocity 20 m/s in the opposite direction, hits the ring at a height of 0.75 m and goes vertically up with velocity 10 m/s. Immediately after the collision, **(IIT-JEE 2011)**



(a) the ring has pure rotation about its stationary CM

(b) the ring comes to a complete stop

(c) friction between the ring and the ground is to the left

(d) there is no friction between the ring and the ground

Comprehension Based/Passage Based

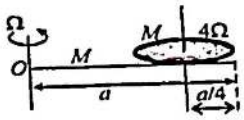
Direction (Q. 107-108): A pendulum consists of a bob of mass $m = 0.1$ kg and a massless inextensible string of length $L = 1.0$ m. It is suspended from a fixed point at height $H = 0.9$ m above a frictionless horizontal floor. Initially, the bob of the pendulum is lying on the floor at rest vertically below the point of suspension. A horizontal impulse P = 0.2 kg-m/s is imparted to the bob at some instant. After the bob slides for some distance, the string becomes taut and the bob lifts off the floor. The magnitude of the angular momentum of the pendulum about the point of suspension just before the bob lifts off is J kg-m^2/s. The kinetic energy of the pendulum just after the lift off is K Joules. **(JEE Adv. 2021)**

62. The value of J is ____. **C-26.89 W-53.75 UA-19.36**

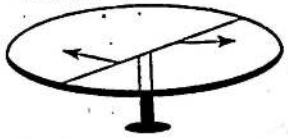
63. The value of K is ____. **C-5.59 W-74.15 UA-20.26**

Numerical Types/Integer Types

64. A thin rod of mass M and length a is free to rotate in horizontal plane about a fixed vertical axis passing through point O. A thin circular disc of mass M and of radius $a/4$ is pivoted on this rod with its center at a distance $a/4$ from the free end so that it can rotate freely about its vertical axis, as shown in the figure. Assume that both the rod and the disc have uniform density and they remain horizontal during the motion. An outside stationary observer finds the rod rotating with an angular velocity Ω and the disc rotating about its vertical axis with angular velocity 4 Ω. The total angular momentum of the system about the point O is $\left(\frac{Ma^2\Omega}{48}\right)n$. The value of n is. **C-3.61 W-73.79 UA-22.6 (JEE Adv. 2020)**



65. A horizontal circular platform of radius 0.5 m and mass 0.45 kg is free to rotate about its axis. Two massless spring toy-guns, each carrying a steel ball of mass 0.05 kg are attached to the platform at a distance 0.25 m from the centre on either side along its diameter (see figure). Each gun simultaneously fires the balls horizontally and perpendicular to the diameter in opposite directions. After leaving the platform, the balls have a horizontal speed of 9ms^{-1} with respect to the ground. The rotational speed of the platform in rad s^{-1} after the balls leave the platform is **C-23.47 W-63.75 UA-12.78 (IIT-JEE 2014)**



66. A uniform circular disc of mass 50 kg and radius 0.4 m is rotating with an angular velocity of 10 rad/s about its own axis, which is vertical. Two uniform circular rings, each of mass 6.25 kg and radius 0.2 m, are gently placed symmetrically on the disc in such a manner that they are touching each other along the axis of the disc and are horizontal. Assume that the friction is large enough such that the rings are at rest relative to the disc and the system rotates about the original axis. The new angular velocity (in rad s^{-1}) of the system is **C-18.2 W-29.79 UA-52.02 (JEE Adv. 2013)**

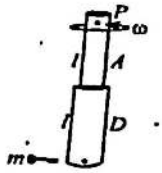
67. A binary star consists of two stars A (mass 2.2 MS) and B (mass 11 MS), where MS is the mass of the sun. They are separated by distance d and are rotating about their centre of mass, which is stationary. The ratio of the total angular momentum of the binary star to the angular momentum of star B about the centre of mass is **(IIT-JEE 2010)**

Fill in the Blanks

68. A particle of mass 1 kg is subjected to a force which depends on the position as with $\vec{F} = -k(x\hat{i} + y\hat{j})$kg ms^{-2}. At time $t = 0$, the particle's position $\vec{r} = \left(\frac{1}{\sqrt{2}}\hat{i} + \sqrt{2}\hat{j}\right)$m and its velocity $\vec{v} = \left(-\sqrt{2}\hat{i} + \sqrt{2}\hat{j} + \frac{2}{\pi}\hat{k}\right)$ ms^{-1}. Let v_x and v_y denote the x and the y components of the particle's velocity, respectively. Ignore gravity. When $z = 0.5$ m, the value of $(xv_y - yv_x)$ is _____ m^2 s^{-1}. **(JEE Adv. 2022)**

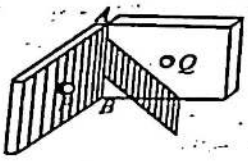
69. A stone of mass m, tied to the end of a string, is whirled around in a horizontal circle. (Neglect the force due to gravity). The length of the string is reduced gradually keeping the angular momentum of the stone about the centre of the circle constant. Then, the tension in the string is given by $T = Ar^n$, where A is a constant, r is the instantaneous radius of the circle. Then n = ... **C-2.62 W-9.61 UA-87.77 (IIT-JEE 1993)**

@FAKE_OBJECT@FAKE_OBJECT



Subjective

70. Two heavy metallic plates are joined together at 90° to each other. A laminar sheet of mass 30 kg is hinged at the line AB joining the two heavy metallic plates. The hinges are frictionless. The moment of inertia of the laminar sheet about an axis parallel to AB and passing through its centre of mass is 1.2 kg-m². Two rubber obstacles P and Q are fixed, one on each metallic plate at a distance 0.5 m from the line AB. This distance is chosen, so that the reaction due to the hinges on the laminar sheet is zero during the impact. Initially the laminar sheet hits one of the obstacles with an angular velocity 1 rad/s and turns back. If the impulse on the sheet due to each obstacle is 6 N-s.



(a) Find the location of the centre of mass of the laminar sheet from AB.

(b) At what angular velocity does the laminar sheet come back after the first impact?

(c) After how many impacts, does the laminar sheet come to rest?

(IIT-JEE 2001)

Energy Analysis

Single Correct

71. One twirls a circular ring (of mass M and radius R) near the tip of one's finger as shown in Figure 1. In the process the finger never loses contact with the inner rim of the ring. The finger traces out the surface of a cone, shown by the dotted line. The radius of the path traced out by the point where the ring and the finger is in contact is r. The finger rotates with an angular velocity ω_0. The rotating ring rolls without slipping on the outside of a smaller circle described by the point where the ring and the finger is in contact (Figure 2). The coefficient of friction between the ring and the finger is μ and the acceleration due to gravity is g.

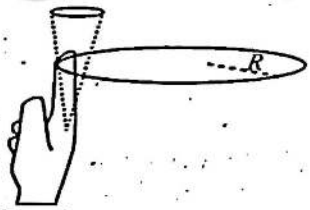


Figure 1

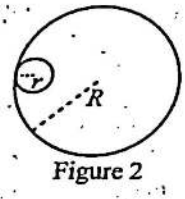


Figure 2

The total kinetic energy of the ring is

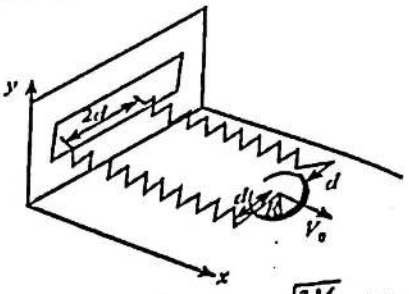
C-100 W-0 UA-0 (JEE Adv. 2017)

(a) $M\omega_0^2(R-r)^2$ (b) $\frac{1}{2}M\omega_0^2(R-r)^2$

(c) $M\omega_0^2R^2$ (d) $\frac{3}{2}M\omega_0^2(R-r)^2$

72. The maximum value of V_0 for which the disk will roll with slipping is

(IIT-JEE 20



(a) $\mu g\sqrt{\frac{M}{k}}$ (b) $\mu g\sqrt{\frac{M}{2k}}$ (c) $\mu g\sqrt{\frac{3M}{k}}$ (d) $\mu g\sqrt{\frac{5M}{2k}}$

73. Two discs A and B are mounted coaxially on a vertical axle. The d have moments of inertia I and $2I$ respectively about the comm axis. Disc A is imparted an initial angular velocity 2ω using the en potential energy of a spring compressed by a distance x_1. Dis is imparted an angular velocity ω by a spring having the same sp constant and compressed by a distance x_2. Both the discs rotate the clockwise direction.

(IIT-JEE 200

The ratio x_1/x_2 is

(a) 2 (b) 1/2 (c) $\sqrt{2}$ (d) $1/\sqrt{2}$

74. Two discs A and B are mounted coaxially on a vertical axle. The d have moments of inertia I and $2I$ respectively about the comm axis. Disc A is imparted an initial angular velocity 2ω using the en potential energy of a spring compressed by a distance x_1. Dis is imparted an angular velocity ω by a spring having the same sp constant and compressed by a distance x_2. Both the discs rotate the clockwise direction. The loss of kinetic energy during the abo process is

(IIT-JEE 200

(a) $\frac{1}{2}I\omega^2$ (b) $\frac{1}{3}I\omega^2$ (c) $\frac{1}{4}I\omega^2$ (d) $\frac{1}{6}I\omega^2$

75. A child is standing with folded hands at the centre of a platfo rotating about its central axis. The kinetic energy of the system is K. The child now stretches his arms so that the moment of iner of the system doubles. The kinetic energy of the system now is

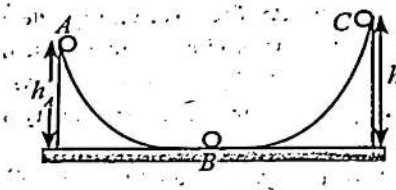
(IIT-JEE 200

(a) $2K$ (b) $\frac{K}{2}$ (c) $\frac{K}{4}$ (d) $4K$

Multiple Correct

76. A ball moves over a fixed track as shown in the figure. From A to the ball rolls without slipping. If surface BC is frictionless and K_B and K_C are kinetic energies of the ball at A, B and C respectiv then

(IIT-JEE 200

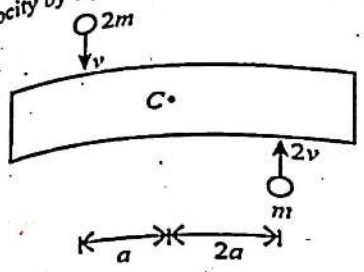


(a) $h_A > h_C; K_B > K_C$ (b) $h_A > h_C; K_C > K_A$

(c) $h_A = h_C; K_B = K_C$ (d) $h_A < h_C; K_B > K_C$

@MAKE_JEE_X@PRIVATE.TUNE

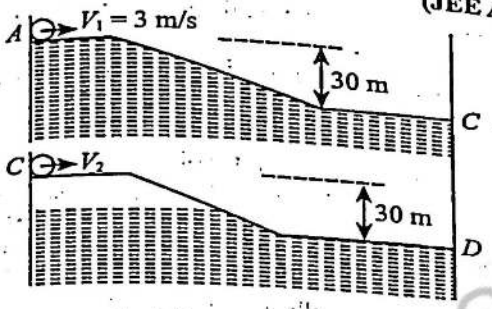
77. A uniform bar of length $6a$ and mass $8m$ lies on a smooth horizontal table. Two point masses m and $2m$ moving in the same horizontal plane with speed $2v$ and v respectively, strike the bar [as shown in the figure] and stick to the bar after collision. Denoting angular velocity (about the centre of mass), total energy and centre of mass velocity by ω, E and v_c respectively, we have after collision



(a) $v_c = 0$ (b) $\omega = 3v/5a$ (c) $\omega = v/5a$ (d) $E = 3/5mv^2$ **(IIT-JEE 1991)**

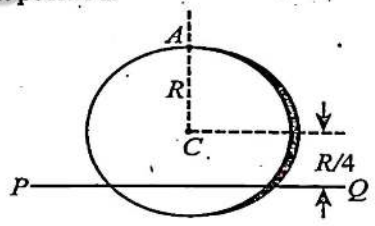
Numerical Types/Integer Types

78. Two identical uniform discs roll without slipping on two different surfaces AB and CD (see figure) starting at A and C with linear speeds v_1 and v_2, respectively, and always remain in contact with the surfaces. If they reach B and D with the same linear speed and $v_1 = 3$ m/s, then v_2 in m/s is **(JEE Adv. 2015)**

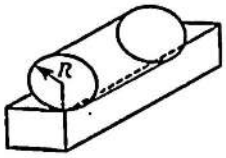


Subjective

79. A uniform circular disc has radius R and mass m. A particle, also of mass m, is fixed at a point A on the edge of the disc as shown in the figure. The disc can rotate freely about a horizontal chord PQ that is at a distance $R/4$ from the centre C of the disc. The line AC is perpendicular to PQ. Initially the disc is held vertical with the point A at its highest position. It is then allowed to fall, so that it starts rotation about PQ. Find the linear speed of the particle as it reaches its lowest position. **(IIT-JEE 1998)**



80. A rectangular rigid fixed block has a long horizontal edge. A solid homogeneous cylinder of radius R is placed horizontally at rest with its length parallel to the edge such that the axis of the cylinder and the edge of the block are in the same vertical plane as shown in figure. There is sufficient friction present at the edge, so that a very small displacement causes the cylinder to roll off the edge without slipping. Determine



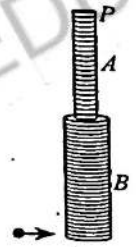
(a) the angle θ, through which the cylinder rotates before it leaves contact with the edge,

(b) the speed of the centre of mass of the cylinder before leaving contact with the edge and

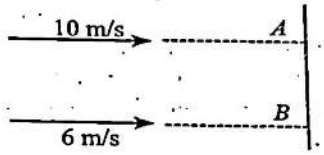
(c) the ratio of the translational to rotational kinetic energies of the cylinder when its centre of mass is in horizontal line with the edge. **(IIT-JEE 1995)**

81. Two uniform rods A and B of length 0.6m each and of masses 0.01 kg and 0.02 kg, respectively are rigidly joined end to end. The combination is pivoted at the lighter end, P as shown in figure. Such that it can freely rotate about point P in a vertical plane.

A small object of mass 0.05 kg, moving horizontally, hits the lower end of the combination and sticks to it. What should be the velocity of the object, so that the system could just be raised to the horizontal position? **(IIT-JEE 1994)**



82. A thin uniform bar lies on a frictionless horizontal surface and is free to move in any way on the surface. Its mass is 0.16 kg and length is $\sqrt{3}$ m. Two particles, each of mass 0.08 kg are moving on the same surface and towards the bar in a direction perpendicular to the bar one with a velocity of 10 m/s, and the other with 6 m/s, as shown in figure. The first particle strikes the bar at points A and the other at point B. Points A and B are at a distance of 0.5 m from the centre of the bar. The particles strike the bar at the same instant of time and stick to the bar on collision. Calculate the loss of kinetic energy of the system in the above collision process. **(IIT-JEE 1991)**



Combined Rotation and Translation

Single Correct

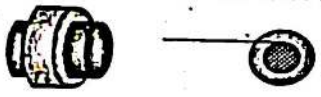
83. A football of radius R is kept on a hole of radius r ($r < R$) made on a plank kept horizontally. One end of the plank is now lifted so that it gets tilted making an angle θ from the horizontal as shown in the figure below. The maximum value of θ so that the football does not start rolling down the plank satisfies (figure is schematic and not drawn to scale) **C-17.81 W-31.98 UA-50.21 (JEE Adv. 2020)**

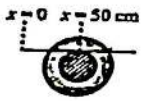
@BOOKS_CBSE_X_@RAJ_EDUKET

(a) $\sin\theta = \frac{r}{R}$ (b) $\tan\theta = \frac{r}{R}$

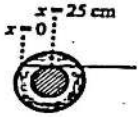
(c) $\sin\theta = \frac{r}{2R}$ (d) $\cos\theta = \frac{r}{2R}$

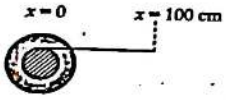
84. A small roller of diameter 20 cm has an axle of diameter 10 cm (see figure below on the left). It is on a horizontal floor and a meter scale is positioned horizontally on its axle with one edge of the scale on top of the axle (see figure on the right). The scale is now pushed slowly on the axle so that it moves without slipping on the axle, and the roller starts rolling without slipping. After the roller has moved 50 cm, the position of the scale will look like (figures are schematic and not drawn to scale) **C-22.83 W-37.4 UA-39.77 (JEE Adv. 2020)**



(a) 

(b)

(c) 

(d) 

85. Two solid cylinders P and Q of same mass and same radius start rolling down a fixed inclined plane from the same height at the same time. Cylinder P has most of its mass concentrated near its surface, while Q has most of its mass concentrated near the axis. Which statement(s) is(are) correct? **(IIT-JEE 2012)**

(a) Both cylinders P and Q reach the ground at the same time

(b) Cylinder P has larger linear acceleration than cylinder Q

(c) Both cylinders reach the ground with same translational kinetic energy

(d) Cylinder Q reaches the ground with larger angular speed

86. **Statement-I:** Two cylinders, one hollow (metal) and the other solid (wood) with the same mass and identical dimensions are simultaneously allowed to roll without slipping down an inclined plane from the same height. The hollow cylinder will reach the bottom of the inclined plane first.

Statement-II: By the principle of conservation of energy, the total kinetic energies of both the cylinders are identical when they reach the bottom of the incline. **(IIT-JEE 2008)**

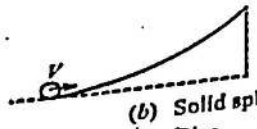
(a) If Statement-I is true, Statement-II is true; Statement-II is the correct explanation for Statement-I

(b) If Statement-I is true, Statement-II is true; Statement-II is not a correct explanation for Statement-I

(c) If Statement-I is true; Statement-II is false

(d) If Statement-I is false; Statement-II is true.

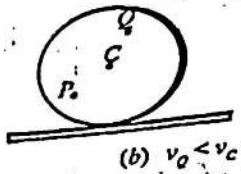
87. A small object of uniform density rolls up a curved surface with an initial velocity v. It reaches up to a maximum height of $(3v^2)/4g$ with respect to the initial position. The object is **(IIT-JEE 2007)**



(a) Ring (b) Solid sphere

(c) Hollow sphere (d) Disc

88. A disc is rolling (without slipping) on a horizontal surface. C is its centre and Q and P are two points equidistant from C. Let v_P, v_Q and v_C be the magnitude of velocities of points P, Q and C respectively. then **(IIT-JEE 2004)**



(a) $v_Q > v_C > v_P$ (b) $v_Q < v_C < v_P$

(c) $v_Q = v_P, v_C = v_P/2$ (d) $v_Q < v_C > v_P$

89. A cylinder rolls up an inclined plane, reaches some height and then rolls down (without slipping throughout these motions). The direction of the frictional force acting on the cylinder are **(IIT-JEE 2002)**

(a) Up the incline while ascending and down the incline while descending

(b) Up the incline while ascending as well as descending

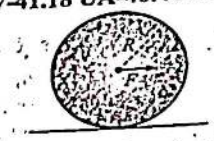
(c) Down the incline while ascending and up the incline while descending

(d) Down the incline while ascending as well as descending

Multiple Correct

90. A horizontal force F is applied at the centre of mass of a cylindrical object of mass m and radius, perpendicular to its axis as shown in the figure. The coefficient of friction between the object and the ground is μ. The centre of mass of the object has an acceleration a. The acceleration due to gravity is g. Given that the object rolls without slipping, which of the following statement(s) is(are) correct?

C-10.17 W-41.18 UA-40.44 PC-8.21 (JEE Adv. 2020)



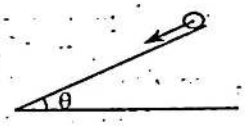
(a) For the same F, the value of a does not depend on whether the cylinder is solid or hollow

(b) For a solid cylinder, the maximum possible value of a is $2\mu g$

(c) The magnitude of the frictional force on the object due to the ground is always μmg

(d) For a thin-walled hollow cylinder, $a = \frac{F}{2m}$

91. A solid sphere is in pure rolling motion on an inclined surface having inclination **(IIT-JEE 2006)**



(a) Frictional force acting on sphere is $f = \mu mg\cos\theta$

(b) f is dissipative force

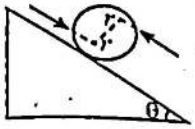
(c) Friction will increase its angular velocity and decrease its linear velocity

(d) If θ decreases, friction will decrease

@MKE_OFFICIAL@RAJEDUNET

Numerical Types/Integer Types

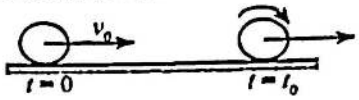
92. A solid sphere of mass 1 kg and radius 1 m rolls without slipping on a fixed inclined plane with an angle of inclination $\theta = 30°$ from the horizontal. Two forces of magnitude 1 N each, parallel to the incline, act on the sphere, both at distance $r = 0.5$ m from the center of the sphere, as shown in the figure. The acceleration of the sphere down the plane is____ ms^{-2}. (Take $g = 10\ ms^{-2}$.) **C-4.15 W-64.60 UA-31.25 (JEE Adv. 2022)**



93. At time $t = 0$, a disk of radius 1 m starts to roll without slipping on a horizontal plane with an angular acceleration of $\alpha = \frac{2}{3}$ rad s^{-2}. A small stone is stuck to the disk. At $t = 0$, it is at the contact point of the disk and the plane. Later, at time $t = \sqrt{\pi}s$, the stone detaches itself and flies off tangentially from the disk. The maximum height (in m) reached by the stone measured from the plane is $\frac{1}{2} + \frac{x}{10}$. The value of x is [Take $g = 10\ ms^{-2}$]. **C-5.03 W-54.12 UA-40.84 (JEE Adv. 2020)**

Subjective

94. A uniform disc of mass m and radius R is projected horizontally with velocity v_0 on a rough horizontal floor, so that it starts off with a purely sliding motion at $t = 0$. After t_0 seconds, it acquires a purely rolling motion as shown in figure. **(JEE Adv. 2021)**



(a) Calculate the velocity of the centre of mass of the disc at t_0.
(b) Assuming the coefficient of friction to be μ, calculate t_0. Also calculate the work done by the frictional force as a function of time and the total work done by it over a time t much longer than t_0.

95. A carpet of mass M made of inextensible material is rolled along its length in the form of a cylinder of radius R and is kept on a rough floor. The carpet starts unrolling without sliding on the floor when a negligibly small push is given to it. Calculate the horizontal velocity of the axis of the cylindrical part of the carpet when its radius reduces to $R/2$. **(IIT-JEE 1990)**

@FAKE_CBSE_X_@RAJ_EDUNET

ANSWER KEY

JEE-Main

1. [728]	2. (d)	3. (a)	4. [16]	5. [53]	6. (c)	7. (4)	8. [32]	9. [3]	10. [5]
11. [1]	12. [5]	13. [5]	14. [17]	15. [110]	16. [176]	17. [5]	18. [15]	19. (a)	20. [5]
21. [5]	22. [8]	23. [5]	24. [3]	25. [5]	26. (d)	27. (d)	28. (c)	29. (c)	30. (d)
31. (c)	32. (b)	33. (d)	34. (c)	35. (a)	36. [8]	37. [52]	38. (a)	39. (b)	40. (b)
41. (c)	42. (a)	43. (d)	44. (b)	45. (b)	46. [11]	47. [25.00]	48. (d)	49. (d)	50. (d)
51. (a)	52. (b)	53. (d)	54. (a)	55. (b)	56. (d)	57. (d)	58. (c)	59. [4]	60. [100]
61. [3]	62. [18]	63. (c)	64. [10]	65. (a)	66. (d)	67. [4]	68. [20]	69. (d)	70. (a)
71. (a)	72. (a)	73. (c)	74. (a)	75. (c)	76. [6]	77. (b)	78. [50.00]	79. (b)	80. [25.60]
81. (c)	82. (d)	83. [60]	84. (a)	85. [250]	86. (24)	87. [8]	88. [13]	89. (c)	90. [800]
91. [16]	92. [35]	93. [4]	94. [3]	95. (a)	96. (c)	97. [91]	98. (c)	99. [3]	100. (b)
101. (a)	102. (c)	103. [10]	104. [49]	105. (d)	106. (c)	107. (a)	108. (b)	109. [20]	110. [9.00]
111. [20]	112. (a,c,d)	113. (d)	114. (a)	115. (c)	116. (c)	117. (d)	118. (b)	119. (d)	120. [7.00]
121. [10]	122. [6]	123. (c)	124. [7]	125. [2]	126. (3)	127. (a)	128. [2]	129. [3]	130. [54]
131. [2]	132. [10]	133. [40]	134. (a,b,c,d)	135. [75]	136. (d)	137. [2.86]	138. [0.52]	139. (b)	140. [3]
141. [5]	142. [120]	143. [3]	144. (d)	145. [6]	146. [9]	147. (d)	148. (d)	149. [4]	150. (a)
151. (b, d)	152. (b)	153. (a)	154. [15]	155. (b)	156. (b)	157. (b)	158. (d)	159. (d)	160. (a)

JEE-Advanced

1. (c)	2. (a)	3. (d)	4. (a)	5. (c)	6. (b, c)	7. (a, b)	8. [2]	12. [False]	13. (a)
14. (a)	15. (a)	16. (d)	17. (a)	18. (c)	19. (a, b, c)	20. [3]	21. [9]	25. (b)	26. (b)
27. (b)	28. (a)	29. (c)	30. (a; b, c)	31. (a, c)	32. (a,c)	33. (a, c, d)	34. (a, b, c)	35. (a)	36. [4]
44. (a)	45. (b)	46. (c)	47. (d)	48. (c)	49. (a)	50. (b)	51. (b)	52. (c)	53. (a)
54. (b)	55. (b)	56. (b)	57. (c)	58. (a, c, d)	59. (b,c)	60. (c,d)	61. (a,c)	62. [0.18]	63. [0.162]
64. [49]	65. [4]	66. [8]	67. (6)	71. (c)	72. (c)	73. (c)	74. (b)	75. (b)	76. (a, b)
77. (a,c,d)	78. [7]	83. (a)	84. (b)	85. (d)	86. (d)	87. (d)	88. (a)	89. (b)	90. (b, d)
91. (c,d)	92. [2.86]	93. [0.52]							

EXPLANATIONS

JEE-Main

1. [728] $\omega_f = 2460 \times \frac{2\pi}{60} = 82\pi$

$\omega_i = \frac{900 \times 2\pi}{60} = 30\pi$

$\alpha = \frac{\omega_f - \omega_i}{t} = \frac{82\pi - 30\pi}{26}$

$= 2\pi \text{ rad/sec}^2$

$\theta = \frac{\omega_f^2 - \omega_i^2}{2\alpha} = \frac{(82\pi + 30\pi)(82\pi - 30\pi)}{2 \times 2\pi}$

$= \frac{(112 \times 52)\pi^2}{4\pi} = 2\pi n$

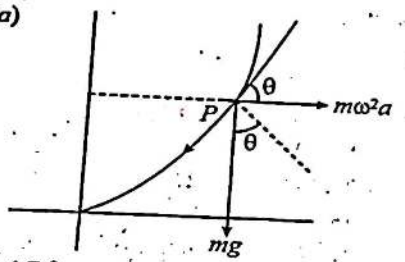
No. of revolution $(n) = \frac{(112 \times 13)\pi}{2\pi} = 728$

2. (d) $a = \omega^2 \times \ell$

$= \left(\frac{2\pi}{T}\right)^2 \times \ell = \left(\frac{2\pi}{60}\right)^2 \times 0.1$

$= 1.1 \times 10^{-3} \text{ m/s}^2$

3. (a)



$y = 4Cx^2$

$\Rightarrow \frac{dy}{dx} = \tan\theta = 8Cx$

At P, $\tan\theta = 8Ca$

For steady circular motion

$mg\sin\theta = m\omega^2 a\cos\theta$

$\Rightarrow \tan\theta = \frac{\omega^2 a}{g}$

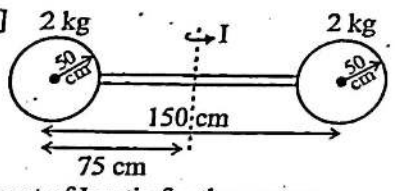
$\Rightarrow 8ca \times g = \omega^2 \times a$

$\Rightarrow \omega = \sqrt{8gC}$

$\Rightarrow \omega = 2\sqrt{2gC}$

4. [16] $I = ma^2 + ma^2 + m(\sqrt{2}a)^2 = 4ma^2$
$= 4 \times 1 \times (2)^2 = 16$

5. [53]



Moment of Inertia for the system,

$I = \left(\frac{2}{5}mR^2 + md^2\right) \times 2$

$I = 2\left(\frac{2}{5} \times 2 \times \left(\frac{1}{2}\right)^2 + 2 \times \left(\frac{3}{4}\right)^2\right)$

$= \frac{53}{20} \text{kg} - \text{m}^2$

$X = 53$,

6. (c) Moment of inertia of the sphere along its diameter,

$I_{\text{sphere}} = \frac{2}{3}MR^2 = Mk_1^2$

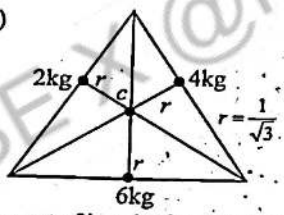
Moment of inertia of the cylinder along the diameter,

$I_{\text{cylinder}} = \frac{1}{12}M(4R^2) + \frac{1}{4}MR^2 + M(2R)^2$

$= \frac{67}{12}MR^2 = Mk_2^2$

$\frac{k_1}{k_2} = \sqrt{\frac{2}{3} \cdot \frac{12}{67}} = \sqrt{\frac{8}{67}}$

7. (4)

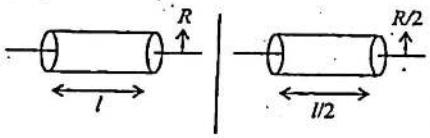


Moment of inertia about and perpendicular to the plane is :

$I = r^2[2 + 4 + 6]$

$= \frac{1}{3} \times 12 = 4 \text{ kg} - \text{m}^2$

8. [32]

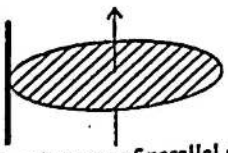


$I_1 = \frac{m_1 R^2}{2}$ and $I_2 = \frac{m_2 (R/2)^2}{2}$

$\Rightarrow \frac{I_1}{I_2} = \frac{4m_1}{m_2} = \frac{4 \cdot \rho\pi R^2 \ell}{\rho \cdot \frac{\pi R^2}{4} \times \frac{\ell}{2}}$

$\Rightarrow \frac{I_1}{I_2} = 32$

9. [3]



Using theorem of parallel axis,

$I = I_{cm} + Md^2$

$I = \frac{MR^2}{2} + MR^2$

$I = \frac{3}{2}MR^2$

$\Rightarrow x = 3$

10. [5] For ring $I = mR_1^2 = mK_1^2$

For solid sphere

$I' = \frac{2}{5}m'R_2^2 = m'K_2^2$

$\therefore$ Radius of gyration $K_1 = R_1$ (For ring)

$\therefore$ Its radius of gyration $= K_2 = \sqrt{\frac{2}{5}}R_2$ (For gyration)

$\because$ Radii of gyration is same.

$\therefore R_1 = \sqrt{\frac{2}{5}}R_2 \Rightarrow \frac{R_1}{R_2} = \sqrt{\frac{2}{5}}$

$\therefore x = 5$

11. [1] Moment of inertia of full ring of mass (2m) and radius (R) is

$I_{\text{Ring}} = 2MR^2$

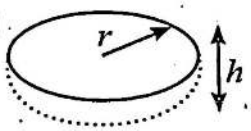
Semicircular ring has same radius (R) and mass is half (M.)

So, moment of inertia of Semicircular ring,

$I_{\text{semicircular ring}} = \frac{I_{Ring}}{2} = \frac{2MR^2}{2} = MR^2$

$\therefore x = 1$

12. [5]



$\because$ Mass of both disc is equal

$\because M_1 = M_2$

$\Rightarrow (\pi r_1^2)h_1\rho_1 = (\pi r_2^2)h_2\rho_2$

$\Rightarrow r_1^2 \times \frac{h_1}{h_2} \times \frac{\rho_1}{\rho_2} = r_2^2 \quad \left[\because \frac{h_1}{h_2} = \frac{1}{0.5} = 2\right]$

$\Rightarrow r_1^2 \times 2 \times \frac{\rho_1}{\rho_2} = r_2^2$

@FAKE_CBSE_X@RAJ_EDUNET

$\Rightarrow \frac{r_1^2}{r_2^2}=\left(\frac{\rho_2}{2\rho_1}\right)=\left(\frac{5}{6}\right)\left[\text{Given, }\frac{\rho_2}{\rho_1}=\frac{5}{3}\right]$

$\text{Ratio of M.O.I} = \frac{\frac{1}{4}Mr_1^2}{\frac{1}{4}Mr_2^2}=\left(\frac{r_1^2}{r_2^2}\right)=\left(\frac{5}{6}\right)$

13. [5] For solid sphere, Moment of inertia,

$I=\frac{2}{5}mR^2$

$\therefore mk_{sph}^2=\frac{2}{5}mR^2$

$k_{sph}=\sqrt{\frac{2}{5}}R$

Similarly,

For solid cylinder $mk_{cyl}^2=\frac{mR^2}{2}$

$\Rightarrow k_{cyl}=\frac{R}{\sqrt{2}}$

$\frac{k_{sph}}{k_{cyl}}=\frac{\sqrt{\frac{2}{5}}}{\frac{1}{\sqrt{2}}}=\frac{2}{\sqrt{5}}=\frac{2}{\sqrt{x}}$

$\therefore x=5$

14. [17] Moment of inertia of a circular disc about centre of mass and perpendicular to its plane $I_{cm}=\frac{mR^2}{2}$

Using parallel axis theorem

$I_{AB}=\frac{mR^2}{2}+m\left(\frac{2R}{3}\right)^2=\frac{17}{18}mR^2$

$\therefore \frac{I_{AB}}{I_{cm}}=\frac{17}{9} \quad \Rightarrow x=17$

15. [110] Moment of inertia of a solid sphere about the center of mass,

$I_{cm}=\frac{2}{5}MR^2$

Using parallel axis theorem

$\Rightarrow I_{PQ}=I_{cm}+md^2$

$I_{PQ}=\frac{2}{5}mR^2+m(10\,cm)^2$

For radius of gyration

$I_{PQ}=mk^2$

$k^2=\frac{2}{5}R^2+(10\,cm)^2$

$=\frac{2}{5}(5)^2+100=110$

$\Rightarrow k=\sqrt{110}\,cm$

$\therefore x=110$

16. [176] Moment of inertia of the system
$I=2\,(I_{cm}+md^2)$

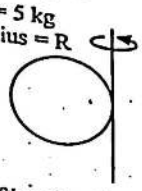
$=2\left(\frac{2}{5}mr^2+md^2\right)$

$=\frac{4}{5}\times 2\times(0.1)^2+2(2)(0.20)^2$

$=\frac{8}{5}\times 10^{-2}+16\times 10^{-2}$

$I=176\times 10^{-3}\,kg\,m^2$

17. [5] $m_1=5$ kg
Radius = R



Moment of inertia of a solid sphere about an axis passing through its center,

$I_1=\frac{2}{5}m_1R^2$.

Using theorem of parallel axis,

$I_1=\frac{2}{5}m_1R^2+m_1R^2 \quad I_1=m_1R^2\left(\frac{7}{5}\right)$

$\Rightarrow I_1=7R^2 \qquad [\because m_1=5\text{kg}]$

For a disc, moment of inertia about an axis passing along its diameter $I=\frac{m_2R^2}{4}$

Using theorem of parallel axis,

$I_2=\frac{m_2R^2}{4}+m_2R^2$

$I_2=\frac{5}{4}m_2R^2$

$I_2=5R^2$

$\Rightarrow \frac{I_2}{I_1}=\frac{5}{7}$

$x=5$

18. [15] Torque acting on the cylinder. $\tau=I\alpha$
$\Rightarrow FR=mR^2\alpha \ (\because \tau=\text{Force}\times r_\perp)$

$\alpha=\frac{F}{mR}=\frac{52.5}{5\times 0.7}=15 rads^{-2}$

19. (a) Moment of inertia of solid sphere about any tangent, $I=I_{cm}+mr^2 \ \frac{2}{5}mr^2+mr^2$

$=\frac{7}{5}mr^2$

Moment of inertia of hollow sphere about any tangent,
$I=I_{cm}+mr^2$

$=\frac{2}{3}mr^2+mr^2=\frac{5}{3}mr^2$.

M.O.I of circular ring about its diameter,
$I=\frac{MR^2}{2}$

M.O.I of circular disc about any diameter,
$I=\frac{MR^2}{4}$

20. [5] Radius of gyration,

$k=\sqrt{\frac{I}{m}}=\sqrt{\frac{m\ell^2/12}{m}}=\frac{\ell}{2\sqrt{3}}$

$\Rightarrow k=\frac{10\sqrt{3}}{2\sqrt{3}}=5$

21. [5] $I_1=\frac{2}{5}M(2R)^2=\frac{8}{5}MR^2$

$I_2=\frac{M(2R)^2}{2}=2MR^2$

$I_3=\frac{M(2R)^2}{4}=MR^2$

$I_4=\frac{M(2R)^2}{2}=2MR^2$

According to question,
$2(I_2+I_3)+I_4=xI_1$

$\Rightarrow 2\left(2MR^2+MR^2\right)+2MR^2=x\frac{8}{5}MR^2$

$\Rightarrow x=5$

22. [8] $I_1=\frac{ML^2}{3}$

Now, $2\pi r=L$

$\Rightarrow r=\frac{L}{2\pi}$

$I_2=\frac{1}{2}Mr^2=\frac{1}{2}\frac{ML^2}{4\pi^2}$

So, $\frac{I_1}{I_2}=\frac{8\pi^2}{3} \Rightarrow x=8$

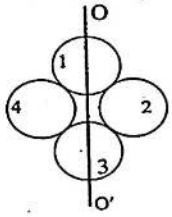
23. [5] Radius of gyration,

$k=\sqrt{\frac{I}{m}}=\sqrt{\frac{m\ell^2/12}{m}}=\frac{\ell}{2\sqrt{3}}$

$\Rightarrow k=\frac{10\sqrt{3}}{2\sqrt{3}}=5$

24. [3] $I_1=I_3=\frac{Ma^2}{4\times 4}, I_2=I_4=\frac{Ma^2}{4\times 4}+\frac{Ma^2}{4}$

$I_{00'}=I_1+I_2+I_3+I_4$



@FAKE CBSE X @UNLEDNET

$$I_{ac} = \frac{6Ma^2}{8} = \frac{3}{4}Ma^2$$

$\Rightarrow x = 3$

25. [5] Radius of gyration,

$$k = \sqrt{\frac{I}{m}} = \sqrt{\frac{m\ell^2/12}{m}} = \frac{\ell}{2\sqrt{3}}$$

$$\Rightarrow k = \frac{10\sqrt{3}}{2\sqrt{3}} = 5$$

26. (*d*) $I_x = I_y = \frac{MR^2}{4}$

If radius of gyration is K_1, then,

$$I_z = I_x = MK_1^2 \Rightarrow K_1 = \frac{R}{2}$$

Similarly,

$$I_z = \frac{MR^2}{2} = MR_{K_2}^2 \Rightarrow K_2 = \frac{R}{\sqrt{2}}$$

Hence, $K_1 \neq K_2$

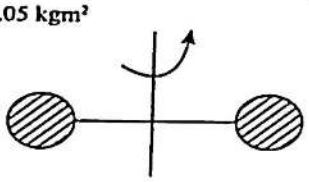
27. (*d*) Given: $M = 1.5$ kg, $r = 0.5$ m, $d = 5/2$ m

Using parallel axis theorem:

$$I = 2\times\left[\frac{2}{5}Mr^2 + Md^2\right]$$

$$I = 2\times\left[\frac{2}{5}(1.5)(0.5)^2 + (1.5)(2.5)^2\right]$$

$= 19.05$ kgm^2



28. (*c*) (*a*) $I = \frac{ML^2}{12}$

(*b*) $I = \frac{(2M)L^2}{3}$

(*c*) $I = \frac{M(2L)^2}{12} = \frac{ML^2}{3}$

(*d*) $I = \frac{(2M)(2L)^2}{3} = \frac{8ML^2}{3}$

29. (*c*) Moment of Inertia of bigger disc about axis AB,

$$I_1 = \frac{1}{2}MR^2 = \frac{1}{2}\sigma\pi R^2.R^2 \quad [\because M = \sigma\pi R^2]$$

Moment of Inertia of bigger disc about axis CD,

$$I_2 = \frac{1}{4}mr^2 = \frac{1}{4}\sigma\pi r^2.r^2 \quad [\because m = \sigma\pi r^2]$$

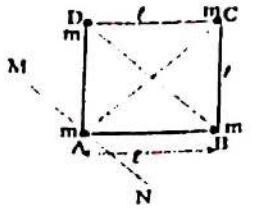
Therefore, $\frac{I_1}{I_2} = \frac{\left(\frac{1}{2}\sigma\pi R^2.R^2\right)}{\left(\frac{1}{4}\sigma\pi r^2.r^2\right)} = 4$

$$= \frac{2R^4}{r^4}$$

30. (*d*)

$$I_{MN} = m(0)^2 + m(\sqrt{2}\ell)^2 + m\left(\frac{\ell}{\sqrt{2}}\right)^2 \times 2$$

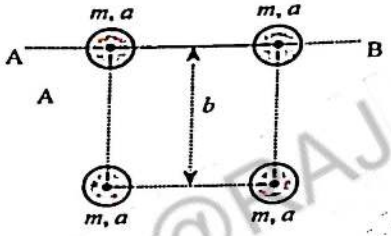
$\Rightarrow I_{MN} = 2m\ell^2 + m\ell^2 = 3m\ell^2$



31. (*c*) Moment of inertia about side AB of the square.

$$I_{AB} = \frac{2}{5}ma^2 \times 2 + \left(\frac{2}{5}ma^2 + mb^2\right)\times 2$$

$$= \frac{8ma^2}{5} + 2mb^2$$



32. (*b*) Given, that,

Radius of cylinder, $r = 0.2$ m,

length of cylinder, $L = 0.8$ m

and moment of inertia along CD, $I = 2.7$ kg m^2.

$$I_{CD} = \frac{1}{2}Mr^2 + M\left(\frac{L}{2}\right)^2$$

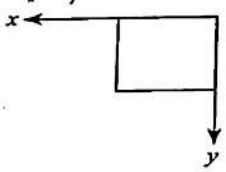
$$\Rightarrow 2.7 = M\left(\frac{0.2^2}{2} + \frac{0.8^2}{4}\right)$$

$\Rightarrow M = 15$ kg

Density, $\rho = \frac{M}{\pi r^2 L} = \frac{15}{3.14\times 0.2^2 \times 0.8}$

$= 1.49 \times 10^2$ kg/m^3

33. (*d*) $\because I_z = I_x + I_y$



$$\therefore I_z = \frac{m\ell^2}{3} + \frac{m\ell^2}{3} = \frac{2}{3}m\ell^2$$

34. (*c*) We know that,

$$I_1 = \frac{1}{2}mr^2,\ I_2 = \frac{1}{2}mr^2,\ I_3 = \frac{1}{2}mr^2,$$

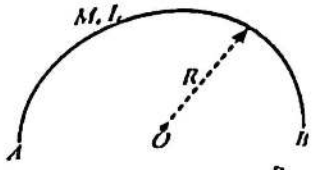
$$I_4 = \frac{2}{5}mr^2$$

$\therefore I_1 = I_2 = I_3 > I_4$

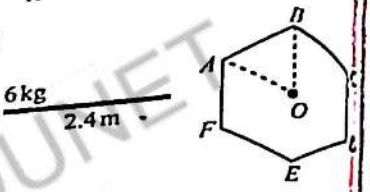
35. (*a*) According to the question, perimeter of semi-circle = Length of wire.

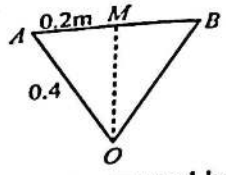
$$\pi R = L \Rightarrow R = \frac{L}{\pi}$$

$$I_O = MR^2 = M\left(\frac{L}{\pi}\right)^2 = \frac{ML^2}{\pi^2}$$



36. [8]





Let us suppose, $m_{AB} = m = 1$ kg

$AB = 2.4/6 = 0.4$ m $= \ell$

$$d = OM = \sqrt{0.4^2 - 0.2^2}$$

$$= \sqrt{0.12} = 2\sqrt{3}\times 10^{-1}\text{ m}$$

$$I_{AB,\text{about }O} = \frac{m\ell^2}{12} + md^2$$

$$\therefore I_{\text{hexagon, about }O} = 6 \times I_{AB,\text{ about }O}$$

$$= 6\left[\frac{m\ell^2}{12} + md^2\right] = \frac{m\ell^2}{2} + 6md^2$$

$$= \frac{1\times(0.4)^2}{2} + 6\times 1\times(2\sqrt{3}\times 10^{-1})^2$$

$$= \frac{0.16}{2} + 6\times 4\times 3\times 10^{-2}$$

$= 8 \times 10^{-1}$ kgm^2

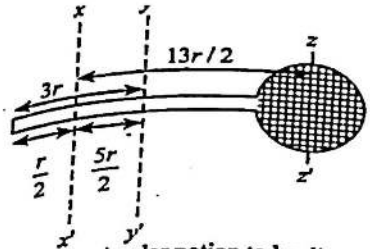
37. [52]

$$I_{xx'} = \left[I_{y'} + M\left(\frac{5r}{2}\right)^2\right] + \left[I_{zz'} + M\left(\frac{13r}{2}\right)^2\right]$$

$$= M\left(\frac{36r^2}{12}\right) + \frac{M\times 25r^2}{4} + \frac{Mr^2}{2}$$

$$+ M\times\frac{169Mr^2}{4} = 52Mr^2$$

@FAKE_CBSE_@RAJ_EDUNET



Assuming circular potion to be disc

38. (a) Moment of inertia of uniform disc,

$$I=\frac{MR^2}{2}$$

$$I=\frac{\left[(\rho\pi R^2)t\right]R^2}{2}$$

[Where ρ is uniform density and t in thickens

$I_1 \propto R_1^2$ & $I_2 \propto R_2^2$

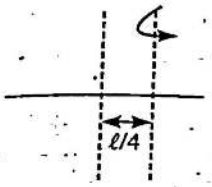
$$\frac{I_1}{I_2}=\left(\frac{R_1}{R_2}\right)^2=\frac{1}{\alpha^2}=\frac{1}{16}$$

$\alpha=4$

39. (b) Moment of inertia

$$I=\frac{M\ell^2}{12}+\frac{M\ell^2}{16}=\frac{7M\ell^2}{48}$$

Comparing with I = Mk² [k = Radius of inration]



40. (b) $\sigma=A+Br$

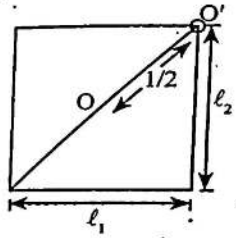
$$I=\int dmr^2=\int_0^a (A+Br)2\pi r^3 dr$$

$$=2\pi\left(A\frac{a^4}{4}+B\frac{a^5}{5}\right)=2\pi a^4\left(\frac{A}{4}+\frac{Ba}{5}\right)$$

41. (c) $\ell_1=0.6$ m

$\ell_2=0.8$ m

$\sqrt{\ell_1^2+\ell_2^2}=1$



Moment of inertia about

$$O, I_1=\frac{M}{12}\left(\ell_1^2+\ell_2^2\right)\Rightarrow I_1=\frac{M}{12}$$

Moment of inertia about O',

$$I_2=\frac{M}{12}\left(\ell_1^2+\ell_2^2\right)+\frac{M\left(\ell_1^2+\ell_2^2\right)}{4}=\frac{M}{3}$$

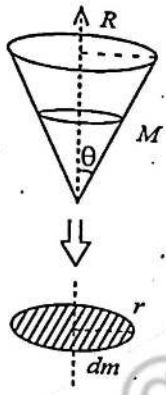
The required ratio, $\frac{I_1}{I_2}=\frac{1}{4}$

42. (a) It can be assumed as stacks of rings having different radii, so $dI=dmr^2$

$$\Rightarrow dm=\left(\frac{M}{\pi RL}\right)2\pi r dL$$

$$\therefore I=\int_0^H \tan^3\theta\left(\frac{2n}{RH}\right)x^3dx$$

$$=\frac{MR^2}{2}$$



43. (d) Moment of inertia, about O,

$$I_O=3\left[\frac{2}{5}M\left(\frac{d}{2}\right)^2+M\left(\frac{d}{\sqrt{3}}\right)^2\right]=\frac{13}{10}Md^2$$

Moment of inertia about A

$$I_A=2\left[\frac{2}{5}M\left(\frac{d}{2}\right)^2+M\left(d^2\right)\right]$$

$$+\frac{2}{5}M\left(\frac{d}{2}\right)^2=\frac{23}{10}Md^2$$

The required ratio, $\frac{I_O}{I_A}=\frac{13}{23}$

44. (b) Mass of material $M=(\pi R^2L\rho)$ ...(i)

$$\therefore I=M\left(\frac{R^2}{4}+\frac{L^2}{12}\right)=M\left(\frac{M}{4\pi\rho L}+\frac{L^2}{12}\right)$$

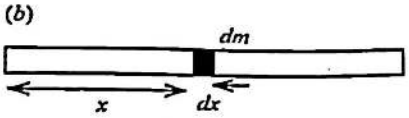
∴ For I to be minimum

$$=\frac{dI}{dL}=0=M\left(-\frac{M}{4\pi\rho L^2}+\frac{L}{6}\right)$$

$$\Rightarrow \frac{M}{\pi\rho L}=\frac{4}{6}L^2$$

$$\Rightarrow R^2=\frac{2}{3}L^2 \quad \Rightarrow \frac{L}{R}=\sqrt{\frac{3}{2}}$$

45. (b)



$$dm=\lambda dx=\lambda_0\left(1+\frac{x}{L}\right)dx$$

$$M=\lambda_0\int_0^L\left(1+\frac{x}{L}\right)dx=\lambda_0 L+\lambda_0\frac{L}{2}=\frac{3\lambda_0 L}{2}$$

...(1)

$$dI=dmx^2=\lambda_0\left(1+\frac{x}{L}\right)dx\times x^2$$

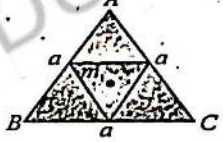
The moment of inertia about an axis passing through A and perpendicular to the road,

$$I=\lambda_0\left\{\int_0^L x^2dx+\frac{1}{L}\int_0^L x^3dx\right\}=\lambda_0\left\{\frac{L^3}{3}+\frac{L^3}{4}\right\}$$

$$I=\frac{7\lambda_0L^3}{12}=\frac{7}{12}\left(\frac{2M}{3L}\right)L^3=\frac{7}{18}ML^2$$

Hence, option (b) is correct answer.

46. [11]



Let I_0 be MI of lamina is about 'G' perpendicular to plane

$\therefore I_0=kma^2$ ...(i)

Then MI of $(m_1)=\frac{km}{4}\frac{a^2}{4}=\frac{I_0}{16}$

Let moment of inertia of one triangular part (side) be I_1 about 'G' then

From symmetry

$$3I_1+\frac{I_0}{16}=I_0 \Rightarrow 3I_1=I_0-\frac{I_0}{16}=\frac{15I_0}{16}$$

$$\Rightarrow I_1=\frac{5I_0}{16}$$

So, moment of inertia of remaining portion

$$I''=2I_1+\frac{I_0}{16}=\frac{11}{16}I_0$$

47. [25.00] $I=0+ma^2+m\left(\frac{a}{2}\right)^2$

[According to parallel axis theorem]

$$I=ma^2+\frac{ma^2}{4}=\frac{5ma^2}{4}$$

$$\Rightarrow N=25.00$$

48. (d) $I=I_C+mx^2$

$$I_C=\frac{2}{5}mR^2$$

@FAKE_CBSE_@RAJ_EDUNET

$$I = \frac{2}{5}mR^2 + mx^2$$

Graph will be parabola opening upward.

49. (d) $I_1 = \dfrac{\left(\frac{7M}{8}\right)(2R)^2}{2} = \left(\frac{7}{16}\times 4\right)MR^2$

$$= \frac{7}{4}MR^2$$

$$I_2 = \frac{2}{5}\left(\frac{M}{8}\right)R_1^2 = \frac{2}{5}\left(\frac{M}{8}\right)\frac{R^2}{4} = \frac{MR^2}{80}$$

$$\frac{4}{3}\pi R^3 = 8\left(\frac{4}{3}\pi R_1^3\right)$$

$$R^3 = 8R_1^3$$

$$R = 2R_1$$

$$\therefore \frac{I_1}{I_2} = \frac{7/4MR^2}{\frac{MR^2}{80}} = \frac{7}{4}\times 80 = 140$$

50. (d)

$$dI = (dm)r^2 = (\sigma\, dA)r^2$$

$$= \left(\frac{\sigma_0}{r}2\pi r dr\right)r^2$$

$$= (\sigma_0\, 2\pi)r^2 dr$$

$$= I = \int dI = \int_a^b \sigma_0 2\pi r^2 dr$$

$$\sigma_0 2\pi\left(\frac{b^3 - a^3}{3}\right)$$

$$m = \int dm = \int \sigma dA = \sigma_0 2\pi \int_a^b dr$$

$$m = \sigma_0 2\pi\,(b-a)$$

Radius of gyration

$$k = \sqrt{\frac{I}{m}} = \sqrt{\frac{\left(b^3 - a^3\right)}{3(b-a)}}$$

$$k = \sqrt{\left(\frac{a^2 + b^2 + ab}{3}\right)}$$

51. (a) $I = 2\left[\frac{2}{5}MR^2 + M4R^2\right] + M\frac{4R^2}{12}$

$$= MR^2\left[\frac{1}{3} + \frac{4}{5} + 8\right] = \frac{137}{15}MR^2$$

52. (b) The moment of inertia of the system about OO',

$$I = \frac{MR^2}{2} + 2\left(\frac{MR^2}{4} + MR^2\right) = 3\,MR^2$$

53. (d) Here, $dm = \sigma dA = \sigma 2\pi r dr$

$$\Rightarrow M = r\pi K\frac{R^4}{4} = \frac{1}{2}\pi KR^4 \qquad \ldots(I)$$

Moment of Inertia about the axis of the disc.

$$I = \int dI = \int dmr^2$$

$$\Rightarrow I = 2\pi K\int_0^R r^3 dr = \frac{\pi KR^4}{3} \qquad \ldots(II)$$

From (I) and (II) we get

$$I = \frac{2}{3}MR^2$$

Hence, option (d) is correct answer.

54. (a) Let M is mass and a is side of triangle ABC.

$$\frac{I_{DEF}}{I_0} = \frac{\left(\frac{M}{4}\right)\left(\frac{a}{2}\right)^2}{M(a)^2}$$

$$I_{DEF} = \frac{I_0}{16}$$

Moment of inertia of remaining sheet

$$I_0 = \frac{I_0}{16} = \frac{15I_0}{16}$$

55. (b) As hollow cylinder and thin cylinder have same moment of intertia and mass.

$$\frac{M}{2}\left(R_1^2 + R_2^2\right) = MR^2$$

$$\frac{R_1^2 + R_2^2}{2} = R^2$$

$$\therefore R = \frac{10^2 + 20^2}{2} = 15.8$$

$$R = 16 \text{ cm}$$

56. (d) $M = \int_0^R \rho_0 r(2\pi r dr) = \frac{\rho_0 \times 2\pi \times R^3}{3}$

I_0 (MOI about COM)

$$= \int_0^R \rho_0 r(2\pi r dr) \times r^2 = \frac{\rho_0 \times 2\pi R^5}{5}$$

by parallel axis theorem

$$I = I_0 + MR^2$$

$$= \frac{\rho_0 \times 2\pi R^5}{5} + \frac{\rho_0 \times 2\pi R^3}{3} \times R^2$$

$$= \rho_0 2\pi R^5 \times \frac{8}{15}$$

$$= MR^2 \times \frac{8}{5}$$

57. (d) Here, $dm = \sigma dA = \sigma 2\pi r dr$

$$\Rightarrow M = r\pi K\frac{R^4}{4} = \frac{1}{2}\pi KR^4 \qquad \ldots(i)$$

Moment of Inertia about the axis of the disc.

$$I = \int dI = \int dmr^2$$

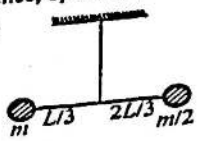
$$\Rightarrow I = 2\pi K\int_0^R r^3 dr = \frac{\pi KR^6}{3} \qquad \ldots(ii)$$

From (I) and (II) we get

$$I = \frac{2}{3}MR^2$$

Hence, option (d) is correct answer.

58. (c)



$$\omega = \sqrt{\frac{k}{I}};\ \Omega = \Omega_0 \times \omega$$

$$T = m\Omega^2\frac{\ell}{3} \qquad \{\because T = m\Omega^2 r\}$$

$$T = m\omega^2\frac{\ell}{3}\theta_0^2 \left\{I = m\frac{\ell^2}{3} \text{ and } \omega = \sqrt{\frac{k}{I}}\right\}$$

$$= \frac{\theta_0^2 k}{\ell}$$

59. [4] Given: Impulse J = 0.2 N-S

$$J = \int F dt = 0.2\text{N} - \text{s}$$

Angular impulse $(\bar{M})$

$$\bar{M}_c = \int \tau dt$$

$$= \frac{L}{2}\int F dt = \frac{L}{2}\times J \qquad = \frac{0.3}{2}\times 0.2$$

$$= 0.03$$

$$I_{cm} = \frac{ML^2}{12} = \frac{2\times(0.3)^2}{12} = \frac{0.09}{6}$$

$$M = I_{cm}(\omega_f - \omega_i)$$

$$0.03 = \frac{0.09}{6}(\omega_f) \Rightarrow \omega_f = 2 \text{ rad/s}$$

$$t = \frac{\theta}{\omega} = \frac{\pi}{2\times 2} = \frac{\pi}{4}\text{sec.}$$

$$\therefore X = 4$$

60. [100] Torque, $\tau = FR = I\alpha \Rightarrow 40 \times 0.1$
$= 0.4\alpha$
$\alpha = 10 \text{ rad/s}^2$
$W_f = 10 \times 10 = 100 \text{ rad/s}$

61. [3] $\bar{\tau} = \bar{r} \times \bar{F}$

$$\bar{r} = (0-2)\hat{i} + (0-(-3))\hat{j} = -2\hat{i} + 3\hat{j}$$

$$\therefore \bar{\tau} = (-2\hat{i} + 3\hat{j}) \times (-P\hat{k}) = P(-3\hat{i} - 2\hat{j})$$

$$\Rightarrow P(a\hat{i} + b\hat{j}) = P(-3\hat{i} - 2\hat{j})$$

$$\frac{a}{b} = \frac{3}{2} \Rightarrow x = 3$$

62. [18] $r = 1.5\text{m}, F = 12t - 3t^2\text{N}, I = 4.5 \text{ kgm}^2$
Torque, $\tau = I\alpha$

@RAKESH_CBSE_@RAJEDUNET

$$\alpha=\frac{\tau}{I}=\frac{1.5\times(12t-3t^2)}{4\cdot5}=\frac{1}{3}(12t-3t^2)$$

$$\Rightarrow \alpha=4t-t^2$$

$$\frac{d\omega}{dt}=4t-t^2=\int d\omega=\int(4t-t^2)_0^t\,dt$$

$$\omega=2t^2-\frac{t^3}{3}$$

For $\omega=0$,

$$0=2t^2-\frac{t^3}{3}=t^2\left(2-\frac{t}{3}\right)=0$$

$t=0, 6s$

Since, $\omega=\frac{d\theta}{dt}\Rightarrow d\theta=\omega dt$

$$\Rightarrow\int_0^0 d\theta=\int_0^6\left(2t^2-\frac{t^3}{3}\right)dt$$

$$\theta=\left[\frac{2t^3}{3}-\frac{t^4}{12}\right]=\left[\frac{t^2}{3}\left(2t-\frac{t^2}{4}\right)\right]_0^6$$

$$=\frac{36}{3}\left(12-\frac{36}{4}\right)=36\text{ rad.}$$

No. of revolutions $=\frac{36}{2\pi}=\frac{18}{\pi}\Rightarrow k=18$

63. (c) We have,

$\vec{F}=5\hat{i}+3\hat{j}-7\hat{k}, \vec{r}=2\hat{i}+2\hat{j}+\hat{k}$

$$\vec{\tau}=|\vec{r}\times\vec{F}|=\begin{vmatrix}\hat{i}&\hat{j}&\hat{k}\\2&2&1\\5&3&-7\end{vmatrix}=-17\hat{i}+19\hat{j}-4\hat{k}$$

64. [10] From the free body diagram,

$2g-T=2a$ ...(i)

Rotation equation for disc of mass M

$T_R=\frac{MR^2}{2}\alpha$ ...(ii)

$\alpha=\frac{a}{R}$ ...(iii)

Solving (i), (ii) and (iii), we get

$T=g=10$ N.

65. (a) Using diagram (a), (b) and (c)

$mg-T=ma$ ... (i)

$T\times r=I\alpha$ ... (ii)

$a=\alpha r$ ...(iii)

Using equation (i), (ii) and (iii).

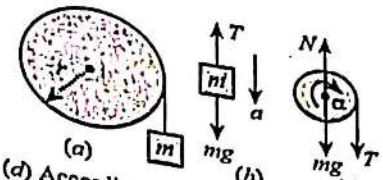
$$mg-\frac{I\alpha}{r}=ma\Rightarrow mg-\frac{Ia}{r^2}=ma$$

$$a\left(m+\frac{I}{r^2}\right)=mg$$

$$a=\frac{mg}{m+\frac{I}{r^2}}$$

Now $\omega^2r^2=2ah=\frac{2mgh}{m+\frac{I}{r^2}}$

$$\omega^2=\frac{2mgh}{I+mr^2}$$



66. (d) According to question the given data is,

$\vec{F}=4\hat{i}-3\hat{j}$

$\vec{r}_1=5\hat{i}+5\sqrt{3}\hat{j}, \vec{r}_2=-5\hat{i}+5\sqrt{3}\hat{j}$

Torque about 'O' we know that, $\vec{\tau}=\vec{r}\times\vec{F}$

$\vec{\tau}_O=\vec{r}_1\times\vec{F}=(-15-20\sqrt{3})\hat{k}$

$=(15+20\sqrt{3})(-\hat{k})$

Torque about 'Q'

$\vec{\tau}_Q=\vec{r}_2\times\vec{F}=(-15+20\sqrt{3})\hat{k}$

$=(15-20\sqrt{3})(-\hat{k})$

67. [4] Torque, $\tau=I\alpha$

$$=\frac{MR^2}{2}\left[\frac{\omega_2-\omega_1}{\Delta t}\right]$$

$$=\frac{(10\times400\times10^{-4})}{2}\times\left[\frac{0-600\times\frac{2\pi}{60}}{10}\right]$$

$=4\pi\times10^{-1}$ Nm

68. [20] $|\vec{F}|=4\hat{i}+3\hat{j}+4\hat{k}$

$\vec{r}=2\hat{i}-(2\hat{i}+3\hat{j}+4\hat{k})=-(3\hat{j}+4\hat{k})$

$$|\vec{\tau}|=|\vec{r}\times\vec{F}|=\begin{vmatrix}\hat{i}&\hat{j}&\hat{k}\\0&-3&-4\\4&3&4\end{vmatrix}=-12\hat{j}-16\hat{k}$$

$|\vec{\tau}|=20$

Therefore, magnitude of torque about point (2, 3, 4) is 20.

69. (d) $mgh=\frac{1}{2}mv^2+\frac{1}{2}I\omega^2$

$v=\omega r$ (no slipping)

$$mgh=\frac{1}{2}m\omega^2r^2+\frac{1}{2}\frac{mr^2}{2}\omega^2$$

$$mgh=\frac{3}{4}m\omega^2r^2$$

$$\omega=\sqrt{\frac{4gh}{3r^2}}=\frac{1}{r}\sqrt{\frac{4gh}{3}}$$

70. (a) $\vec{r}=\{-3i-j+2k\}$

$\vec{F}=i+2j+3k$

$$\tau=\begin{vmatrix}i&j&k\\-3&-1&2\\1&2&3\end{vmatrix}$$

$=I(-3-4)-J(-9-2)+k(-6+1)$

$=-7I+11J-5k$

$=\sqrt{7^2+11^2+5^2}$

$=\sqrt{49+121+25}=\sqrt{195}$

71. (a) Using torque equatiion about point P, $\tau=\alpha I$

$$\therefore\alpha=\frac{\tau}{I}=\frac{5M_0g\ell-4M_0g\ell}{5M_0\ell^2+2M_04\ell^2}$$

$$=\frac{M_0g\ell}{13M_0\ell^2}=\frac{g}{13\ell}$$

72. (a) Force,

$\vec{F}=m\vec{a}=m[-a\omega_1^2\cos\omega_1t\hat{i}-b\omega_2^2\sin\omega_2t\hat{j}]$

$\vec{F}_{t=0}=-ma\omega_1^2\hat{i}$

Position of the particle at $t=0$

$\vec{r}_{t=0}=(x_0+a)\hat{i}+y_0\hat{j}$

$\vec{\tau}=\vec{r}\times\vec{F}=my_0a\omega_1^2\hat{k}$

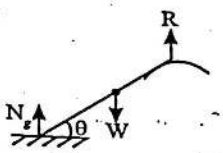
Hence, option (a) is correct answer.

73. (c) Torque about O = 0

$120\left(\frac{L}{2}\cos60^\circ\right)-N_2\,L=0$

$N_2=30$ N

74. (a)

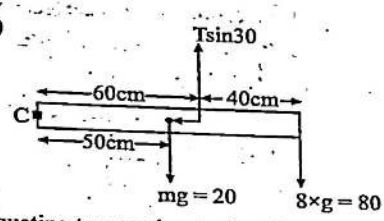


Balancing torque about pt of contact on ground:

$R(L\cos\theta)=W\left(\frac{L}{2}\cos\theta\right)$

$\Rightarrow R=\frac{W}{2}$

75. (c)

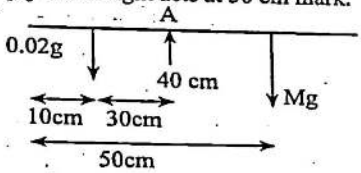


Equating torque about point C

$\frac{T}{2}\times60=20\times50+80\times100$

$\Rightarrow T=300$ N

76. [6] The weight acts at 50 cm mark.



@FAKE_CBSE_MAJ_EDUNET

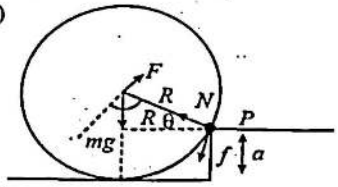
Balancing torque about knife edge,

$2Mg \times 30 = Mg \times 10$

$(20 \times 10^{-3})g(30 \times 10^{-2}) = Mg \times (10 \times 10^{-2})$

$\Rightarrow Mg = 6 \times 10^{-2}$ kg $\Rightarrow x = 6$

77. (*b*)



$FR > mg\cos\theta R$

$F > mg\cos\theta$

$$F > mg\sqrt{\frac{R^2-(R-a)^2}{R}}$$

$$\Rightarrow Mg\sqrt{1-\left(\frac{R-a}{R}\right)^2}$$

78. [50.00] For no toppling

$$F\left(\frac{a}{2}+b\right) \le mg\frac{a}{2}$$

$$\mu\frac{a}{2}+\mu b \le \frac{a}{2} \qquad (F=\mu mg)$$

$0.2a + 0.4b \le 0.5a$

$0.4b \le 0.3a$

$$b \le \frac{3a}{4}$$

$b \le 0.75a$ (in limiting case)

$$\therefore \left(100\frac{b}{a}\right)_{max} = 50.00$$

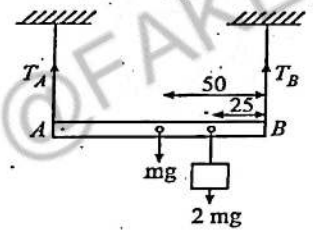
79. (*b*) τ_{net} about B is zero at equilibrium

$T_A\,100 - mg \times 50 - 2\,mg \times 25 = 0$

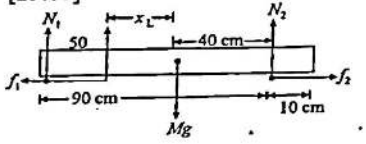
$T_A \times 100 = 100\,mg$

$\Rightarrow T_A = 1\,mg$

Hence, option (*b*) is correct answer



80. [25.60]



Initially $N_1 + N_2 = mg$

Torque about center is zero that is

$N_1(50) = 40N_2 \Rightarrow 5N_1 = 4N_2$

Solving above equations we get

$$N_1 = \frac{4Mg}{9} \text{ and } N_2 = \frac{5Mg}{9}$$

Using definitions of kinetic and static frictions,

$f_{K_1} = 0.32N_1$, $f_{K_2} = 0.32N_2$ and

$f_{L_1} = 0.4N_1$, $f_{L_2} = 0.4N_2$

Suppose x_L is the distance of left finger from centre when right finger starts moving. From rotational equilibrium condition

$N_1x_L = N_2(40)$

and $f_{K_1} = f_{L_2} \Rightarrow 0.32N_1 = 0.40N_2$

$\Rightarrow 4N_1 = 5N_2$

Therefore, $N_1x_L = \frac{4N_1}{5}(40)$

or $x_L = 32$

Now x_R = distance when right finger stops and left finger starts moving

Again, $N_1x_L = N_2(x_R)$

and $f_{L_1} = f_{K_2} \Rightarrow 0.4N_1 = 0.32N_2$

$\Rightarrow 5N_1 = 4N_2$

So, $\frac{4N_2}{5}(32) = N_2x_R$

$$\Rightarrow x_R = \frac{128}{5} = 25.6\,cm$$

81. (*c*) As rod will be in equilibrium from a rotating frame.

So net torque about the point of suspension must be zero.

$$= \tau_A(\text{centrifugal}) = \int_0^L \frac{m}{L}dx\omega^2x^2\sin\theta\cos\theta$$

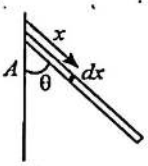
$$= \frac{m}{L}\omega^2\sin\theta\cos\theta\left[\frac{x^3}{3}\right]_0^L$$

$$= \frac{m\omega^2L^2\sin\theta\cos\theta}{3}$$

$\tau_{mg} = \tau_A$ (centrifugal)

$$mg\frac{L}{2}\sin\theta = \frac{m\omega^2L^2\sin\theta\cos\theta}{3}$$

$$\cos\theta = \frac{3g}{2L\omega^2}$$

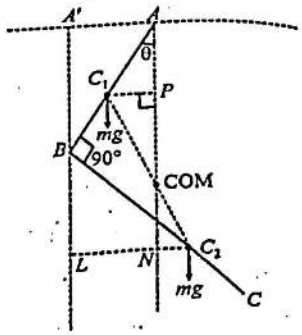


82. (*d*) Lets consider mass of each rod is m.

For stable equilibrium the torque about point O should be zero.

$$mg\frac{a}{2}\sin\theta = mg\left(\frac{a}{2}\cos\theta - a\sin\theta\right)$$

$$\tan\theta = \frac{1}{3}$$



$$\Rightarrow \tan^{-1}\left(\frac{1}{3}\right)$$

83. [60] $y - x - 4 = 0$

d_1 si perpendicular distance of given line from origin.

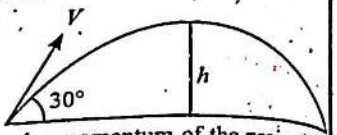
$$d_1 = \left|\frac{-4}{\sqrt{1^2+1^2}}\right| \Rightarrow 2\sqrt{2}\text{ m}$$

The angular momentum of the particle about the origin

$$|\vec{L}| = mvd_1 = 5\times3\sqrt{2}\times2\sqrt{2}\text{ kg m}^2/\text{s}$$

$= 60$ kg m^2/s

84. (*a*)



Angular momentum of the projectile is given by

$L = mv_hr_{perpendicular} = m(v\cos\theta)h$

where, h is the maximum height.

$L = mu\cos\theta\,h$

$$= mu\cos\theta\times\frac{u^2\sin^2\theta}{2g}$$

$$= \frac{mu^3}{2g}\times\frac{\sqrt{3}}{2}\times\left(\frac{1}{2}\right)^2 = \frac{\sqrt{3}mu^3}{16g}$$

85. [250] $\vec{L}_i = I\omega_i = \frac{MR^2}{2}.\omega = 100\text{kgm}^2/\text{s}$

$$E_i = \frac{1}{2}\cdot\frac{MR^2}{2}\cdot\omega^2 = 500\text{ J}$$

$\vec{L}_i = \vec{L}_f \Rightarrow 100 = 2I\omega_f$

$\omega_f = 5$ rad/sec

$$E_f = 2\times\frac{1}{2}\cdot\frac{5(2)^2}{2}\cdot(5)^2 = 250\text{ J}$$

$\Delta E = 250$ J

86. (24) moment of inertia of two discs,

$I_1 = 4$ kg m^2

$I_2 = 2$ kg m^2

$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega_0$ (C.O.A.M.)

@FAKE_CBSE_X_@RAJ_EDUNET

gives ω_0

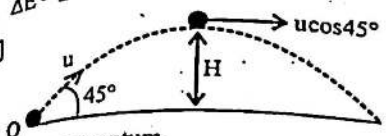
$E_1 = \frac{1}{2}I_1\omega_1^2 + \frac{1}{2}I_2\omega_2^2 = 216J$

$E_2 = \frac{1}{2}(I_1 + I_2)\omega_0^2 = 192J$

The loss in kinetic energy of the system in the process

$\therefore \Delta E = 24J$

87. [8]



Angular momentum,

$L = mu\cos\theta\frac{u^2\sin^2\theta}{2g}$

$= mu^3\frac{1}{4\sqrt{2}g} \Rightarrow x = 8$

88. (13) From the conservation of angular momentum, $I\omega$ = const.

$I_2\omega_2 = I_1\omega_1$

$\frac{2}{5}M\left(\frac{3}{4}R\right)^2\frac{2\pi}{T_2} = \left(\frac{2}{5}MR^2\right)\frac{2\pi}{T_1}$

$\frac{9}{16T_2} = \frac{1}{T_1}$

$T_2 = \frac{9}{16}\times T_1 = \frac{9}{16}\times 24 \text{ hr}$

$= 13.5 \text{ hr.} = 13 \text{ hr } 30 \text{ mins.}$

89. (c) Net torque on the system is zero so angular momentum remains constant

$I_1\omega = I_2\omega_2$

$\frac{MR^2}{2}\omega = \frac{3}{2}\left(\frac{MR^2}{2}\right)\omega_2$

$\omega_2 = \frac{2}{3}\omega$

90. [800] $\because \left|\vec{L}\right| = \int_0^t \tau dt$

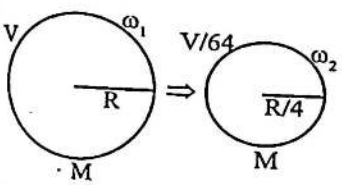
$\left|\vec{L}\right| = \int_0^2 mg(v_x t)dt$

$= mgv_x\frac{t^2}{2} \quad [\because v_x = v\cos 45°]$

$= (0.1)(10)\left(10\sqrt{2}\right)\frac{2^2}{2}$

$= \sqrt{800}\, kg\, m^2/s$

91. [16]



Using conservation of angular momentum

$\frac{2}{5}MR^2\omega_1 = \frac{2}{5}M\left(\frac{R}{4}\right)^2\omega_2$

$\Rightarrow MR^2\omega_1 = \frac{MR^2}{16}\omega_2$

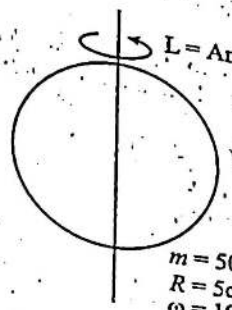
$\Rightarrow \frac{\omega_1}{\omega_2} = \frac{1}{16} \Rightarrow \frac{T_1}{T_2} = \frac{1}{16} \Rightarrow \frac{T_1}{T_2} = \frac{16}{1}$

$\because T_1 = 24\ h$

$\therefore T_2 = \frac{24}{16} \Rightarrow x = 16$

92. [35] Angular momentum about diameter, $L_d = I_d\omega$

$= \frac{2}{5}mR^2\omega$



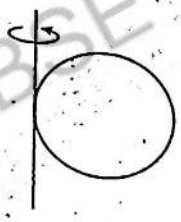
$m = 500 \text{ g} = 0.5 \text{ kg}$
$R = 5\text{cm}$
$\omega = 10 \text{ rad/sec}$

moment of inertia about tangent I_T

$= I_C + mR^2$

$= \frac{2}{5}mR^2 + mR^2$

$= \frac{7}{5}mR^2$



$I_T = x \times 10^{-2}L_d$

$\frac{7}{5}mR^2 = x\times 10^{-2}\times\frac{2}{5}mR^2\omega$

$\frac{7}{20} = x\times 10^{-2} \Rightarrow x = \frac{7}{20}\times 100 = 35$

93. [4] $L=(I_c)(\omega)$ and $K = \frac{1}{2}(I_c)(\omega^2) + \frac{1}{2}MV_c^2$

$L = \frac{2}{5}MR^2\frac{V_c}{R}, K = \frac{1}{2}\left(\frac{2}{5}MR^2\right)\frac{V_c^2}{R^2} + \frac{1}{2}MV_c^2$

$L = \frac{2MRV_c}{5}, K = \frac{7}{10}MV_c^2$

Ratio,

$\frac{L}{K} = \frac{4}{7}\frac{R}{V_c} = \frac{\pi}{22} \Rightarrow \omega = \frac{4}{7}\times\frac{22}{22}\times 7 = 4$

94. [3] From conservation of angular momentum

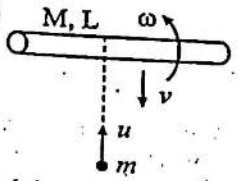
$I_1\omega_1 = I_2\omega_2$

$I\omega = 3I\omega_2 \Rightarrow \omega_2 = \frac{\omega}{3}$

Kinetic energy $E_2 = \frac{1}{2}I_2\omega_2^2$

$E_2 = \frac{1}{2}\times 3I\times\left(\frac{\omega}{3}\right)^2 = \frac{\frac{1}{2}I\omega^2}{3} = \frac{E}{3}$

95. (a)



Applying the conservation of angular momentum about hinge,

$mu\frac{L}{2} + 0 = -mv\frac{L}{2} + \frac{ML^2}{3}\omega \quad ...(i)$

$0.1\times 5\times 0.1$

$= -0.1\times v\times 0.1 + \frac{1\times(0.2)^2}{3}\omega$

$\Rightarrow \omega = (5+v)\times\frac{3}{4} \quad ...(i)$

Also from eq. of restitution

$e = 1 = \frac{\omega\frac{L}{2} + V}{u} \Rightarrow u = \omega\frac{L}{2} + V$

$\Rightarrow 5 = \omega\times 0.1 + v$

$\Rightarrow v = 5 - 0.1\,\omega \quad ...(ii)$

From (i),

$\omega = 5\times\frac{3}{4} + \frac{3}{4}(5 - 0.1\omega)$

$\omega \approx 6.98$ rad/sec

From (ii), $v = 4.30$ m/s

Hence option (a)

96. (c) By conservation of Angular momentum, $L_i = L_f$

$MR^2\omega = (mR^2 + 2mR_2)\omega'$

$\Rightarrow \omega' = \frac{2M}{M+2m}$

97. [91] Angular momentum

$\vec{L} = \vec{r}\times m\vec{v} = m(\vec{r}\times\vec{v})$

$= 1\times(3\hat{i} - \hat{j})\times(3\hat{j} + \hat{k})$

$= 9\hat{k} + 3(-\hat{j}) - \hat{i} = -\hat{i} - 3\hat{j} + 9\hat{k}$

$|\vec{L}| = \sqrt{1+9+81} = \sqrt{91}$

98. (c) $L = I_{cm}\omega + Mv_{cm}R$

$= \left(\frac{2}{3}R^2\right)\omega + (1)(R\omega)R = \frac{5}{3}R^2\omega$

$\Rightarrow a = 5$

@FAKE_CBSE_X @RAJ_EDUNET

99. [3] The line of action of the force passes through the origin. Therefore, the torque about the origin will be zero and as a result, the angular momentum about the origin will remain conserved. Thus,

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{1}{\sqrt{2}} & \sqrt{2} & 0 \\ -\sqrt{2} & \sqrt{2} & \frac{2}{\pi} \end{vmatrix} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ x & y & 0.5 \\ v_x & v_y & \frac{2}{\pi} \end{vmatrix}$$

Equating coefficient of $\hat{k}$,

$[1+2] = [xv_y - yv_x]$

Thus, $xv_y - yv_x = 3$

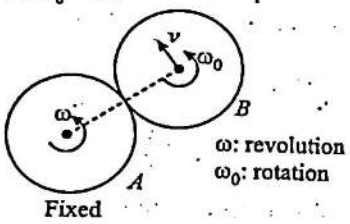
100. (*b*) If the linear velocity of center of mass of disc B is v, then

$v = \omega\,(2R)$

Further, since the disc B is rolling without slipping,

$v = \omega_0 R$: no slipping

$\therefore\ \omega_0 = 2\omega$



ω: revolution

ω_0: rotation

$$\vec{L} = m\vec{r} \times \vec{v}_c + I_c\omega_0 = MRv + \frac{1}{2}MR^2\omega_0$$

$$= 4MR^2\omega + \frac{1}{2}MR^2(2\omega) = 5MR^2\omega$$

$\therefore\ n = 5$

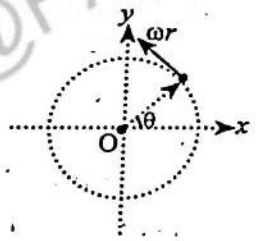
101. (*a*) $\vec{L}_A = Mvr\hat{k} = M\omega r^2\hat{k}$

$\vec{L}_B = (r\cos\theta\hat{i} + \sin\theta\hat{j} - \ell\cos\alpha\hat{k})$

$\times(M\omega r)(-\sin\theta\hat{i} + \cos\theta\hat{j})$

Where $\theta = \omega t$

Magnitude $\vec{L}_B$ is constant and direction changes with time



102. (*c*) Angular momentum

$\vec{L} = \vec{r} \times \vec{p} \Rightarrow \vec{L} = mvr(\hat{k})$

Direction & magnitude both remain same for particle moving with constant speed.

103. [10] Position of the particle,

$\vec{r} = 10\alpha t^2\hat{i} + 5\beta(t-5)\hat{i}$

Velocity of the Particle,

$$\vec{v} = \frac{d\vec{r}}{dt} = 20\alpha t\hat{i} + 5\beta\hat{j}$$

Formula of angular momentum,

$\vec{L} = m(\vec{r} \times \vec{v})$

According to question, $\vec{L}_{t=t} = \vec{L}_{t=0}$

$\Rightarrow \vec{r} \times \vec{v} = \vec{0}$

$\Rightarrow 50\alpha\beta t^2\hat{k} - 100\alpha\beta t(t-5)\hat{k} = \vec{0}$

$\Rightarrow t = 10$ seconds

104. [49] $L_s = L_{disc} + L_{rod}$

$$L_{disc} = \vec{r} \times M\vec{v}_{cm} + I_{cm}4\Omega,\ L_{rod} = \frac{Ma^2}{3}\Omega$$

$$\Rightarrow L_s = \frac{3a}{4} \times \frac{3a}{4} \times M\Omega + \frac{Ma^2}{32} \times 4\Omega + \frac{Ma^2}{3}\Omega$$

$$= \frac{49}{48}Ma^2\Omega$$

105. (*d*) Using conservation of Angular momentum along axis of rotation, we have

$Mr^2\omega = (Mr^2 + 2mr^2)\omega_n$

$$\Rightarrow w_n = \frac{Mw}{M+2m}$$

106. (*c*) From conservation of Angular momentum,

Initial angular momentum = Final angular momentum

$\Rightarrow I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega$

$$\Rightarrow \omega = \frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2} \quad ...(i)$$

Initial kinetic energy,

$$KE_i = \frac{1}{2}I_1\omega_1^2 + \frac{1}{2}I_2\omega_2^2 \quad ...(ii)$$

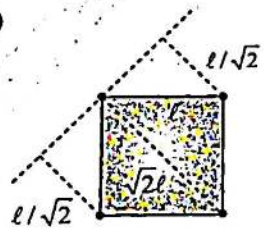
Final kinetic energy,

$$KE_f = \frac{1}{2}(I_1 + I_2)\omega^2 \quad ...(iii)$$

From equation (*i*), (*ii*) and (*iii*),

$$\Rightarrow |KE_f - KE_i| = \frac{1}{2}\left(\frac{I_1I_2}{I_1 + I_2}\right)(\omega_1 - \omega_2)^2$$

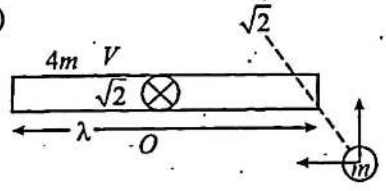
107. (*a*)



$$I = m\left(\frac{\ell^2}{2}\right) \times 2 + m \times (\sqrt{2}\ell)^2 = 3m\ell^2$$

$\therefore\ L = I\omega = 3\,m\ell^2\omega$

108. (*b*)



Angular momentum conserved about O

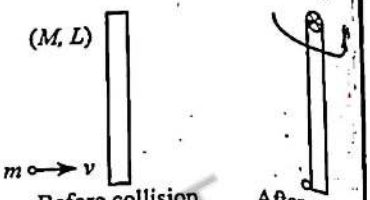
$L_{oi} = L_{of}$

$$\frac{mv}{\sqrt{2}} \times \frac{\ell}{2} = \left[\frac{4m\ell^2}{12} + \frac{m\ell^2}{4}\right] \times \omega$$

$$\omega = \frac{6v}{7\sqrt{2}\ell} = \frac{3\sqrt{2}v}{7\ell}$$

109. [20] Here, we have given that mass of rod $M = 0.9$kg, $\ell = 1$ m, mass of particle $= 0.1$ kg.

Now, angular momentum is conserved because net torque is zero. $\vec{L}_i = \vec{L}_f$



$mvL = I\omega$

$$mvL = \left(\frac{ML^2}{3} + mL^2\right)\omega$$

$$0.1 \times 80 \times 1 = \left(\frac{0.9 \times 1^2}{3} + 0.1 \times 1^2\right)\omega \Rightarrow 8 = \frac{4}{10}\omega$$

$$\omega = 20\frac{\text{rad}}{\text{sec}}$$

110. [9.00] According to conservation of angular momentum

$I_1\omega_1 = I_2\omega_2$

$$(5)\left(\frac{200 \times R^2}{2} + 80R^2\right) = \omega_f\left(\frac{200 \times R^2}{2}\right)$$

$$\Rightarrow \omega_f = \frac{5 \times 180}{100} = 9.00 \text{ rpm}$$

111. [20] Using conservation of angular momentum

$\Rightarrow I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega_f$

$$\Rightarrow \frac{MR^2}{2}\omega_o = \left(\frac{MR^2}{2} + \frac{MR^2}{8}\right)\omega_f$$

$$\Rightarrow \omega_f = \frac{4}{5}\omega_o$$

$$\Rightarrow KE_{final} = \frac{1}{2}(I_1 + I_2)\omega_f^2 = \frac{MR^2\omega^2}{5}$$

$$\Rightarrow KE_{initial} = \frac{1}{2}I\,\omega_0^2 = \frac{MR^2\omega^2}{4}$$

$\Rightarrow$ % loss = 20%.

@FAKE_CBSE_@RAJ_EDUNET

112. (a,c,d)

By the angular momentum conservation about the suspension point.

$$mvx=\left(\frac{mL^2}{3}+mx^2\right)\omega$$

$$\therefore\ \omega=\frac{mvx}{\frac{mL^2}{3}+mx^2}=\frac{3vx}{L^2+3x^2}$$

For maximum $\omega\Rightarrow\frac{d\omega}{dx}=0$

$$\therefore\ x_M=\frac{L}{\sqrt{3}}$$

Putting the above value in ω expression, we get

$$\omega=\frac{v}{2L}\sqrt{3}$$

113. (d) $I\omega=4I\omega'$

$$\Rightarrow\ \omega'=\frac{\omega}{4}$$

$$(\Delta K)_{Loss}=\frac{1}{2}I\omega^2-\frac{1}{2}(4I)\left(\frac{\omega}{4}\right)^2$$

$\Rightarrow$ Fractional los

$$s=\frac{(\Delta K)_{Loss}}{K_1}\left(K_1=\frac{1}{2}I\omega^2\right)=\frac{3}{4}$$

114. (a) $(I_1+I_2)\,\omega=I_1\omega_1+I_2\omega_2$

$$\omega=\frac{0.1\times10+0.2\times5}{0.1+0.2}=\frac{20}{3}\text{ rad/s}$$

$$\text{K.E.}=\frac{1}{2}(I_1+I_2)\omega^2$$

$$=\frac{20}{3}\text{ J}$$

115. (c) Angular momentum conserved about O

$$mvl=\left(\frac{Ml^2}{3}+ml^2\right)\omega$$

$$\Rightarrow\ \omega=\frac{3mv}{3ml+Ml}=\frac{18}{5}\text{ rad/s}$$

Energy conservation

$$\frac{1}{2}\left(\frac{Ml^2}{3}+ml^2\right)\omega$$

$$=\left(Mg\frac{I}{2}+mgI\right)(1-\cos\theta)$$

$$\Rightarrow\ \frac{1}{2}\left(\frac{5}{3}\right)\times\frac{324}{25}=(10+10)(1-\cos\theta)$$

$$\Rightarrow\ 20(1-\cos\theta)=\frac{324}{30}$$

$$\cos\theta=1-\frac{324}{600}=\frac{276}{600}$$

$$=0.46\Leftrightarrow\theta=63^\circ$$

116. (c) $v=\sqrt{5^2+2gh}=\sqrt{5^2+2\times10\times10}$

$$=\sqrt{225}$$

$$=15\text{ m/s}$$

$$L=rmv=20\times(20\times10^{-3}\text{ kg})\times(15)$$

$$=6\text{ kg m}^2\text{/sec}$$

117. (d) Applying angular momentum conservation, about axis of rotation

$$L_i=L_f$$

$$\frac{ML^2}{12}\omega_0=\left(\frac{ML^2}{12}+m\left(\frac{L}{2}\right)^2\times2\right)\omega$$

$$\Rightarrow\ \omega=\frac{M\omega_0}{M+6m}$$

118. (b) Angular momentum conservation.

$$MV_0L=MV_1(L-\ell)$$

$$V_1=V_0\left(\frac{L}{L-\ell}\right)$$

$$w_g+w_p=\Delta KE$$

$$-mg\ell+w_p=\frac{1}{2}m\left(V_1^2-V_0^2\right)$$

$$w_p=mg\ell+\frac{1}{2}mV_0^2\left(\left(\frac{L}{L-\ell}\right)^2-1\right)$$

$$=mg\ell+\frac{1}{2}mV_0^2\left(\left(1-\frac{\ell}{L}\right)^{-2}-1\right)$$

Now, $\ell\ll L$

By, Binomial approximation

$$=mg\ell+\frac{1}{2}mV_0^2\left(\left(1+\frac{2\ell}{L}\right)-1\right)$$

$$=mg\ell+\frac{1}{2}mV_0^2\left(\frac{2\ell}{L}\right)$$

$$W_p=mg\ell+mv_0^2\frac{\ell}{L}$$

here, V_0 = maximum velocity

$$=\omega\times A$$

$$=\left(\sqrt{\frac{g}{L}}\right)(\theta_0L)$$

$$V_0=\theta_0\sqrt{gL}$$

so, $w_p=mg\ell+m\left(\theta_0\sqrt{gL}\right)^2\frac{\ell}{L}$

$$=mg\ell\left(1+\theta_0^2\right)$$

119. (d) $E_i=\frac{1}{2}I_1\times\omega_1^2+\frac{1}{2}\frac{I_1}{2}\times\frac{\omega_1^2}{4}$

$$=\frac{I_1\omega_1^2}{2}\left(\frac{9}{8}\right)=\frac{9}{16}I_1\omega_1^2$$

Conserving angular momentum

$$I_1\omega_1+\frac{I_1\omega_1}{4}=\frac{3I_1}{2}\omega$$

$$\frac{5}{4}I_1\omega_1=\frac{3I_1}{2}\omega$$

$$\omega=\frac{5}{6}\omega_1$$

$$E_f=\frac{1}{2}\times\frac{3I_1}{2}\times\frac{25}{36}\omega_1^2$$

$$=\frac{25}{48}I_1\omega_1^2$$

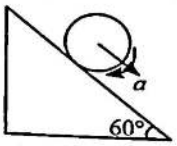
$$E_f-E_i=I_1\omega_1^2\left(\frac{25}{48}-\frac{9}{16}\right)$$

$$=\frac{-I_1\omega_1^2}{24}$$

120. [7.00] Work done by friction is zero in pure rolling. Hence potential energy is converted into kinetic energy.
Finally they will have same kinetic energy because initially the ring and the sphere have same potential energy.
∴ Ratio of kinetic energies = 1

$$\Rightarrow\frac{7}{x}=1\Rightarrow x=7$$

121. [10] Given $\theta=60^\circ$



For rolling motion, $a=\frac{g\sin\theta}{1+\frac{I_{cm}}{MR^2}}$

$$a=\frac{g\sin\theta}{1+\frac{1}{2}}$$

$$=\frac{2\times10\times\frac{\sqrt{3}}{2}}{3}$$

$$=\frac{10}{\sqrt{3}}$$

Therefore $x=10$

122. [6] According to work energy theorem,

$$W=\Delta KE=0-\left(\frac{1}{2}mv^2+\frac{1}{2}I\omega^2\right)$$

$$W=0-\frac{1}{2}mv^2\left(1+\frac{K^2}{R^2}\right)$$

@FAKE_CBSE_X @RAJ_BRUNET

$$= -\frac{1}{2} \times 50 \times 0.4^2 \left(1 + \frac{1}{2}\right) = -6J$$

Absolute work on disk = + 6J

$W = -6\ J\ |W| = 6J$

123. (c) Only the translational kinetic energy of disc changes into gravitational potential energy. And as there is no friction rotational KE remains unchanged.

$$\Rightarrow \frac{1}{2}mv^2 = mgh \Rightarrow h = \frac{v^2}{2g}$$

124. (7) Gain in P.E. = Loss in K.E.

$$\therefore mgh = \frac{1}{2}mv^2\left(1 + \frac{K^2}{R^2}\right)$$

$$\Rightarrow h \propto 1 + \frac{K^2}{R^2}$$

$$\Rightarrow \frac{h_1}{h_2} = \frac{1 + \frac{2}{5}}{1+1} = \frac{7}{5 \times 2} = \frac{7}{10}$$

Therefore, $n = 7$

125. [2] The required ratio of rotational kinetic energy to its total kinetic energy,

$$\frac{\frac{1}{2}I\omega^2}{\frac{1}{2}I\omega^2 + \frac{1}{2}mv^2}$$

$$= \frac{\left(\frac{1}{2}\right)\left(\frac{2}{3}mR^2\right)\omega^2}{\left(\frac{1}{2}\right)\left(\frac{2}{3}mR^2\right)\omega^2 + \frac{1}{2}m(R\omega)^2}$$

$$= \frac{\frac{2}{3}}{\frac{2}{3}+1} = \frac{2}{5}$$

$x = 2$

126. [3] For slipping $a = g\sin\theta$

$$\ell = \frac{1}{2}at^2 \Rightarrow t = \sqrt{\frac{2\ell}{g\sin\theta}}$$

using, $S = ut + \frac{1}{2}at^2$

For rolling

$$a' = \frac{g\sin\theta}{1 + \frac{k^2}{R^2}}\left[k = \frac{R}{\sqrt{2}}\right]$$

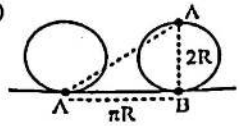
$$\Rightarrow a' = \frac{2g\sin\theta}{3}$$

$$\ell = \frac{1}{2}a'(t')^2$$

$$\Rightarrow t' = \sqrt{\frac{6\ell}{2g\sin\theta}} = \sqrt{\frac{\alpha}{2}}\sqrt{\frac{2\ell}{g\sin\theta}}$$

$\Rightarrow \alpha = 3$

127. (a)



Displacement

$$= \sqrt{(2R)^2 + (\pi R)^2} = R\sqrt{\pi^2 + 4}$$

128. [2] Velocity of the object at the bottom of the plane $v = \sqrt{\frac{2gh}{1 + \frac{k^2}{R^2}}}$

Where h = 60 sin 30° = 30 cm

For a solid cylinder

$$k^2 = \frac{R^2}{2}$$

$$\Rightarrow v = 2\ ms^{-1}$$

129. [3] $(KE)_{Rotational} = \frac{1}{2}I\omega^2 = E$

$$E = \frac{1}{2}\frac{m\ell^2}{12}\omega^2$$

$$E = \frac{1}{2}\frac{dA\ell^3}{12}\omega^2$$

$$E = \frac{dA(2)^3}{24}\omega^2$$

$$\sqrt{\frac{3E}{dA}} = \omega$$

130. [54] $a = -\mu_k g = -3$

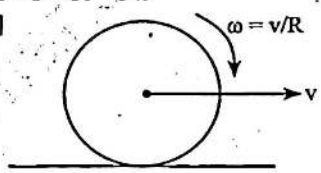
$V = 18 - 3 \times 2$

$V = 12$ m/s

$$KE = \frac{1}{2}mv^2 + \frac{1}{2}\frac{mr^2}{2}\frac{v^2}{r^2} = \frac{3}{4}mv^2$$

$KE = 3 \times 18 = 54J$

131. [2]



Translational Kinetic energy, $K_T = \frac{1}{2}mv^2$

Rotational Kinetic energy,

$$K_R = \frac{1}{2}I\omega^2 = \frac{1}{2}\left(\frac{2}{3}mR^2\right)\frac{v^2}{R^2}$$

$$= \frac{1}{3}mv^2$$

Total $K.E, K = K_T + K_R$

$$= \frac{1}{2}mv^2 + \frac{1}{3}mv^2 = \frac{5}{6}mv^2$$

$$\frac{K_R}{K} = \frac{\frac{1}{3}mv^2}{\frac{5}{6}mv^2} \Rightarrow \frac{x}{5} = \frac{2}{5} \Rightarrow x = 2$$

132. [10] Given, $\frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 = 7 \times 10^{-3}$

$$\frac{1}{2}Mv^2 + \frac{1}{2}\left(\frac{2}{5}MR^2\right)\left(\frac{v}{R}\right)^2 = 7 \times 10^{-3}$$

$$\frac{1}{2}Mv^2\left[1 + \frac{2}{5}\right] = 7 \times 10^{-3}$$

$$\frac{1}{2} \times 1 \times v^2 \times \frac{7}{5} = 7 \times 10^{-3}$$

$\Rightarrow v = 0.1$ m/s = 10 cm/s

133. [40] Total kinetic energy for pure rolling

$$KE = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$2240 = \frac{1}{2}2(v)^2 + \frac{1}{2}\left(\frac{2}{5} \times (2) \times R^2\right)\left(\frac{v}{R}\right)^2$$

$$\because I = \frac{2}{5}MR^2 \Rightarrow 2240 = v^2 + \frac{2}{5}v^2$$

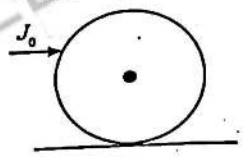
$\Rightarrow v = 40\ m/s$

134. (a,b,c,d) We know that,

$J_0 = mv$ ...(i)

$J_0 h_m = I_c\omega$ ...(ii)

$v = \omega R$ ...(iii)



$$\Rightarrow h_m = \frac{I_c\omega}{J_0} = \frac{I_c\omega}{mv} = \frac{I_c\omega}{m\omega R} = \frac{I_c}{mR}$$

From the options

(a) If $a = 0, I_c = \frac{1}{2}mb^2$ & $R = b$

$$\therefore h_m = \frac{b}{2}$$

(b) If $a = b, I_c = mb^2$ & $R = b$

$\therefore h_m = b$

(c) $v = \frac{J_0}{m} \Rightarrow 100 = \frac{V}{R} = \frac{J_0}{mR}$

(d) Force is acting on center of mass

$\therefore$ No rotation.

135. [75] From the conservation of energy

$KE_i + PE_i = KE_f + PE_f$

$$= \frac{1}{2}mv^2 + \frac{1}{2} \times \frac{2}{3}mR^2 \times \frac{v^2}{R^2} + 0 = 0 + mgh$$

$$\frac{5}{6}mv^2 = mgh$$

$$h = \frac{5}{6 \times 10} \times 9\,m = \frac{15}{20}m = 75\,cm$$

136. (d) Acceleration of an object rolling down the inclined plane,

@FAIZ_CBSE_@RAJ_EDUNET

$$a=\frac{g\sin\theta}{1+\frac{K^2}{R^2}}$$

From kinematic equation

$v^2=0+2as$

$$v=\sqrt{\frac{2gs(\sin\theta)}{1+\frac{K^2}{R^2}}}$$

Therefore,

$$\frac{v_c}{v_s}=\sqrt{\frac{(1+K^2/R^2)c}{(1+K^2/R^2)c}}=\sqrt{\frac{1+2/5}{1+1/2}}=\sqrt{\frac{14}{15}}$$

137. [2.86] Translation motion of COM:

$5+1-1-f=1a$

$5-f=a$ ...(i)

Rotational motion about COM:

$f1-2(1(0.5))=\frac{2}{5}Mr^2\alpha$

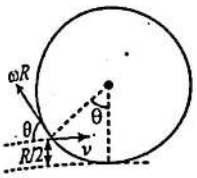
$\Rightarrow f-1=\frac{2}{5}a \Rightarrow f=1+\frac{2}{5}a$ ...(ii)

From equations (i) and (ii),

$5-a=1+\frac{2}{5}a$

$\Rightarrow 4=\frac{7a}{5} \Rightarrow a=\frac{20}{7}=2.86\ m/s^2$

138. [0.52] $\theta=\frac{1}{2}\alpha t^2 \quad \theta=\frac{1}{2}\times\frac{2}{3}\times\pi=\frac{\pi}{3}=60°$



At $t=0, \omega=0$

at $t=\sqrt{\pi}, \omega=\alpha t=\frac{2}{3}\sqrt{\pi}$

$\Rightarrow v=\omega r=\frac{2}{3}\sqrt{\pi}$

Now, $v_y=v\sin60=\frac{\sqrt{3}}{2}v$

So, $h=\frac{v_y^2}{2g}=\frac{\frac{3}{4}v^2}{2g}=\frac{\frac{3}{4}\times\frac{4}{9}\pi}{2g}$

$=\frac{3\pi}{9\times2g}=\frac{\pi}{6g}$

Maximum height from plane, $H=\frac{R}{2}+h$

$H=\frac{1}{2}+\frac{\pi}{6\times10}$

$\Rightarrow x=\frac{\pi}{6}; x=0.52$

139. (b) $K_R=\frac{1}{2}I\omega^2=\frac{1}{2}\times\frac{2}{5}MR^2\times\frac{v^2}{R^2}=\frac{Mv^2}{5}$

$K_T=\frac{1}{2}I\omega^2+\frac{1}{2}Mv^2=\frac{Mv^2}{5}+\frac{1}{2}Mv^2$

$=\frac{7Mv^2}{10}$

Thus, $\frac{K_R}{K_T}=\frac{2}{7}$

140. [3] Given, $M=12$ kg, $m=3$ kg

Net loss in potential energy = Gain in kinetic energy

$Mgh-mgh$

$=\frac{1}{2}mv^2+\frac{1}{2}Mv^2+\frac{1}{2}I\omega^2$ & $w=\frac{v}{r}$

$12\,gh-3\,gh=\frac{1}{2}\times3v^2+\frac{1}{2}\times12v^2$

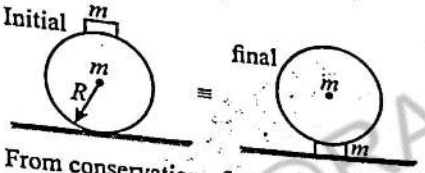
$+\frac{1}{2}(12\times r^2)\times\frac{v^2}{r^2}$

$9\,gh=\frac{1}{2}\times27v^2$

$v=\frac{1}{2}\sqrt{\frac{8}{3}gh} \Rightarrow x=\frac{8}{3}\approx3$

141. [5]

Initial



From conservation of energy,

Gain in K.E = Loss in P.E

$mg(2R)=\frac{1}{2}I_d\omega^2+\frac{1}{2}I_p\omega^2$

or $\frac{1}{2}\left(\frac{1}{2}mR^2+mR^2\right)\omega^2=2mgR$

$\omega=\sqrt{\frac{8g}{3R}}=4\sqrt{\frac{g}{2\times3R}}$

$x=\frac{g}{2}=5$

142. [120] From conservation of energy

Loss in potential energy = gain in kinetic energy.

$mgh=\frac{1}{2}mv^2+\frac{1}{2}I\omega^2$

$\Rightarrow mgh=\frac{1}{2}mv^2+\frac{1}{2}\frac{mR^2}{2}\times\left(\frac{v}{R}\right)^2$

$mgh=\frac{1}{2}mv^2+\frac{1}{4}mv^2$

$10h=\frac{3}{4}\times16$

$h=1.2\text{m}=120\text{ cm}$

143. [3] Acceleration of a body rolling down an inclined plane is,

$$a=\frac{g\sin\theta}{1+\frac{I}{mR^2}}=\frac{g\sin\theta}{1+\frac{1}{2}}=\frac{2}{3}g\sin\theta, b=3$$

144. (d) Translational KE, $K_T=\frac{mv^2}{2}$

Rotational KE, $K_R=\frac{I\omega^2}{2}=\frac{Iv^2}{2R}$

According to question,

$K_R=\frac{1}{2}K_T \Rightarrow \frac{Iv^2}{2R^2}=\frac{1}{2}\times\frac{mv^2}{2}$

$\Rightarrow I=\frac{mR^2}{2}$

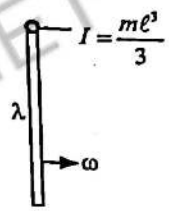
145. [6] $I=\frac{m\ell^2}{3}$

According to energy conservation

$mg\ell=\frac{1}{2}I\omega^2$

$mg\ell=\frac{1}{2}\frac{m\ell^2}{3}\omega^2$

$\Rightarrow\omega=\sqrt{\frac{6g}{\ell}}$



As speed

$v=\omega r=\omega\ell$

then

$V=\sqrt{6g\ell}=\sqrt{6\times10\times.6}$

$\Rightarrow$ 6m/s

146. [9] $\frac{1}{2}\times I_1\omega_1^2=\frac{1}{2}\times I_2\times\omega_2^2$

[I is moment of inertia and ω is angular speed]

$\Rightarrow I_1\times\left(\frac{v}{3R}\right)^2=I_2\times\left(\frac{V}{R}\right)^2$

$\Rightarrow\frac{I_1}{I_2}=\frac{9}{1}=\frac{x}{1}\Rightarrow x=9$

Hence, value of x is 9

147. (d) $K.E_i=K.E_{\text{translational}}+K.E_{\text{rotational}}$

$K_i=\frac{1}{2}mv^2+\frac{1}{2}I\omega^2$

$K_i=\frac{1}{2}mv^2+\frac{1}{2}\left(\frac{2}{5}mr^2\right)\left(\frac{v}{r}\right)^2$

$=\frac{7}{10}mv^2=140J$

$\frac{7}{10}mv_f^2=0.05\times K_i=0.05\times140$

$\Rightarrow v_f^2=20$

$\Rightarrow v_f=\sqrt{20}\approx4.47\,ms^{-1}$

@TAKE_CBSE_X@RAJ_EDUNET

148. (*d*) The minimum value of coefficient of static friction for rolling without slipping on inclined plane will be

$$\mu_{min} = \frac{I\tan\theta}{I+mR^2}$$

$$\Rightarrow \mu_{min} = \frac{\frac{mR^2}{2}\tan\theta}{\frac{mR^2}{2}+mR^2} = \frac{\tan\theta}{3}$$

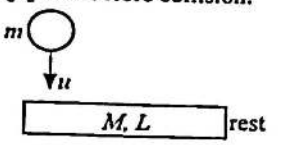
$$= \frac{\tan 60°}{3} = \frac{\sqrt{3}}{3} = \frac{1.732}{3} = 0.5773$$

As coefficient of static friction is less than μ_{min}, therefore body will perform rolling with slipping.

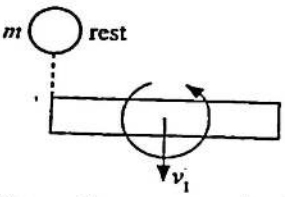
$$\therefore F_K = \mu N = \mu mg\cos\theta$$

$$= (0.4) \times mg\cos 60° = \frac{mg}{5}$$

149. [4] Just before collision:



Just after collision:



From the conservation of linear momentum,

$$mu = Mv_1 \Rightarrow v_1 = \frac{mu}{M} \quad ...(i)$$

Using conservation of angular momentum about centre of mass of Rod,

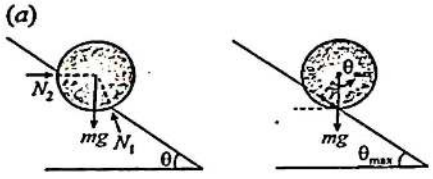
$$\frac{mu\ell}{2} = \frac{M\ell^2\omega}{12} + \frac{mv_1\ell}{2}$$

$$\Rightarrow 6mu = M\ell\omega \Rightarrow \ell\omega = \frac{6mu}{M} \quad ...(ii)$$

Using definition of *e*, and solving (*i*) and (*ii*) we can write

$$v_1 + \frac{\ell\omega}{2} = u \Rightarrow \frac{mu}{M} + \frac{3mu}{M} = u \Rightarrow \frac{m}{M} = \frac{1}{4}$$

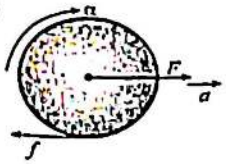
150. (*a*)



For θ_{max}, the football is about to roll, then $N_2 = 0$ and all forces (Mg and N_1) must pass through contact point

$$\therefore \cos(90° - \theta_{max}) = \frac{r}{R} \Rightarrow \sin\theta_{max} = \frac{r}{R}$$

151. (*b*, *d*)



$$F - f = ma_C \quad fR = I_C\alpha$$

$$a_C - \alpha R = 0$$

$$F - I_C\frac{\alpha}{R} = ma_C \Rightarrow a_C = \frac{F}{\frac{I_C}{R^2}+m}$$

So, (*a*) is incorrect

$$f = \frac{I_C\alpha}{R} = \frac{I_C}{R^2}a_C = \frac{I_C}{R^2}\frac{F}{\left[\frac{I_C}{R^2}+m\right]}$$

$$= \frac{F}{\left[1+\frac{mR^2}{I_C}\right]}$$

Thin walled hollow cylinder

$$I_C = mR^2 \Rightarrow a_C = \frac{F}{2m}$$

So, (*d*) is correct

Now, $fR = I_C\alpha = \frac{I_Ca_C}{R}$

$$\Rightarrow f = \frac{I_Ca_C}{R^2} \le \mu mg$$

$$\Rightarrow a_C \le \frac{\mu mgR^2}{I_C} = \mu g$$

For solid cylinder $I_C = \frac{mR^2}{2}$

$$a_C \le 2\mu g$$

$$(a_C)_{max} = 2\mu g$$

So, (*b*) is correct.

152. (*b*) For no slipping at the ground, the center of roller moves with speed

$V_{centre} = \omega R$ (R is radius of roller)

$\therefore$ Velocity of scale = $(V_{center} + \omega r)$

[r is radius of axle]

It is given that $V_{center} \cdot t = 50$ cm

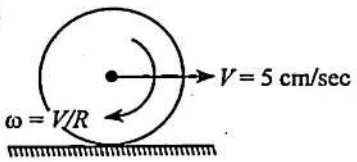
$\therefore$ Distance moved by scale

$= (V_{center} + \omega r)t$

$$= \left(V_{center} + \frac{V_{center}r}{R}\right)t = \frac{3V_{center}}{2}\cdot t$$

$$= 75 \text{ cm} \quad \left(r = \frac{R}{2}\right)$$

153. (*a*)



K.E. of the sphere $= \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

$$K.E. = \frac{1}{2}\left(\frac{2}{5}mR^2 + mR^2\right)\frac{V^2}{R}$$

$$K.E. = \frac{7}{10}\times\frac{1}{2}\times\frac{25}{10^4} = \frac{35}{4}\times10^{-4} \text{ J}$$

$$= 8.75\times10^{-4} \text{ J}$$

154. [15] Here, we have, $mgh = \frac{1}{2}I\omega^2$

[I is moment of inertia and ω is angular speed]

$$mg\frac{\ell}{2}\sin 30° = \frac{1}{2}\frac{m\ell^2}{3}\omega^2$$

Solving,

$\omega^2 = 15 \Rightarrow \omega = \sqrt{15}$

Hence, value of n is 15.

155. (*b*) $K_i + U_i = K_f + U_f$

$$0 + 0 = \frac{1}{2}m_2v^2 + \frac{1}{2}m_1v^2 + \frac{1}{2}I\omega^2 - m_1gh + m_2gh$$

$$(m_1 - m_2)gh = \frac{1}{2}m_2(\omega R)^2 + \frac{1}{2}m_1(\omega R)^2 + \frac{1}{2}I\omega^2$$

$$\sqrt{\frac{2(m_1-m_2)gh}{\left(m_1+m_2+\frac{I}{R^2}\right)R^2}} = \omega$$

156. (*b*) $\frac{1}{2}\left(m + \frac{I}{R^2}\right)v^2 = mgh$

if radius of gyration is k, then $I = mk^2$

$$h = \frac{\left(1+\frac{k^2}{R^2}\right)v^2}{2g}, \quad \frac{k_{ring}}{R_{ring}} = 1 \text{ and}$$

$$\frac{k_{solid\,cylinder}}{R_{solid\,cylinder}} = \frac{1}{\sqrt{2}}$$

$$\frac{k_{solid\,sphere}}{R_{solid\,sphere}} = \sqrt{\frac{2}{5}}$$

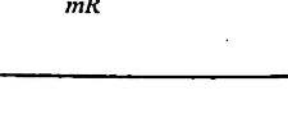
$h_1 : h_2 : h_3 :: (1+1) :$

$$\left(1+\frac{1}{2}\right):\left(1+\frac{2}{5}\right) :: 20:15:14$$

157. (*b*) $40 + f = m(R\alpha)$ ...(i)

$40 \times R - f \times R = mR^2\alpha$

$40 - f = mR\alpha$ ...(ii)



From (*i*) and (*ii*)

$$\alpha = \frac{40}{mR} = 16 \text{ rad/s}^2$$

@FAKE_CBSE_X_@RAJ_EDUNET

158. (d) $F-f=ma$

$fR=\frac{1}{2}mR^2\alpha$

$a=\alpha R$

From above equations,

$F=\frac{3}{2}mR\alpha$

and $\alpha=\frac{2F}{3mR}$

159. (d) **Case 1:** For Solid sphere

$\frac{1}{2}mv^2+\frac{1}{2}\cdot\frac{2}{5}mR^2\cdot\frac{v^2}{R^2}=mgh_{sph}$

$\Rightarrow h_{sph}=\frac{7v^2}{10g}$

Cnse 2: For Solid cylinder

$\frac{1}{2}mv^2+\frac{1}{2}\cdot\frac{1}{2}mR^2\cdot\frac{v^2}{R^2}=mgh_{cyl}$

$\Rightarrow h_{cyl}=\frac{3v^2}{4g}$

$\therefore \frac{h_{sph}}{h_{cyl}}=\frac{7/10}{3/4}=\frac{14}{15}$

160. (a) $KE=\frac{1}{2}I\omega^2\Rightarrow\omega=\sqrt{\frac{2(KE)}{I}}$

$\Rightarrow\omega=\sqrt{\frac{2\times1200}{1.5}}=40\,\text{rad/s}$

$\omega=\omega_0+\alpha t$

$40=0+(20)t\Rightarrow t=\frac{40}{20}=2\,\text{sec}$

JEE-Advanced

1. (c) At t is -

$t=\frac{1}{8}\times\frac{2\pi}{\omega}\Rightarrow t=\frac{\pi}{4\omega}$

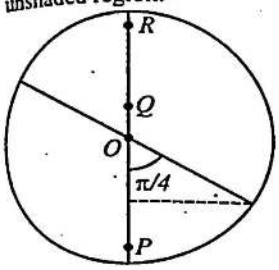
X-coordinate of P

$P=\omega R\left(\frac{\pi}{4\omega}\right)$

$P=\left(\frac{\pi R}{4}\right)>R\cos45°$

Hence,

Both particles P and Q land in an unshaded region.



2. (a) The relative velocity at points P and Q will be $v_r=2\omega r$

Then Relative angle between the velocity vector of the two points will $\theta=\omega_r t$

Hence the resultant relative velocity vector as

$|v_r|=\sqrt{v^2+v^2-2vv\cos(2\omega_r t)}$

$|v_r|=\sqrt{2v^2\times(1-2\cos(2\omega_r t))}$

On solving, we get,

$|v_r|=2v\sin(\omega_r t)$

Hence Magnitude of the relative velocity will have a period of ω.

3. (d) (i) Each particle of the disc is rotating on a horizontal circle.

(ii) Actual velocity of any particle moving in the circle is horizontal.

(iii) Magnitude of velocity of a particle is $v=r\omega$

where, r is the perpendicular distance of that particle from axis of rotation (Z-axis).

(iv) When it gets broken into two parts then actual velocity of a particle is resultant of both the velocities

$v_1=r_1\omega_1$ and $v_2=r_2\omega_2$

Here,

r_1 = perpendicular distance of centre of mass from Z-axis.

ω_1 = angular speed of rotation of centre of mass from Z-axis.

r_2 = distance of particle from centre of mass and ω_2 = angular speed of rotation of the disc about the axis passing through centre of mass.

(v) Resultant v will be horizontal, if v_1 and v_2 are horizontal. Also, v_1 is horizontal, because centre of mass is rotating about a vertical Z-axis. To make v_2 horizontal, second axis should also be vertical.

4. (a) Angular momentum is the product of the moment of inertia and angular velocity.

$L=I\omega$

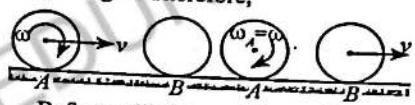
$L=mr^2\left(\frac{v}{r}\right)$

$L=mvr$

i.e. $\vec{L}=m(\vec{r}\times\vec{v})$

When the speed changes, the direction of angular momentum is not changing because of the direction of angular momentum along the axis, perpendicular to the plane of motion. Hence, the direction of Angular momentum remains the same.

5. (c) Since, it is head on elastic collision between two identical spheres, they will exchange their linear velocities, i.e., A comes to rest and B starts moving with linear velocity v. As there is no friction anywhere, torque on both the spheres about their center of mass is zero and their angular velocities remain unchanged. Therefore,



Before collision After collision

6. (b, c) $\vec{V}_A-\vec{V}_B=\vec{r}_A\times\vec{\omega}$ and

$\vec{V}_C-\vec{V}_B=\vec{r}_C\times\vec{\omega}$ and $\vec{r}_A=-\vec{r}_C$

$\Rightarrow\vec{V}_A-\vec{V}_B=-(\vec{V}_C-\vec{V}_B)$

$\Rightarrow|\vec{V}_A-\vec{V}_B|=|\vec{V}_C-\vec{V}_B|$

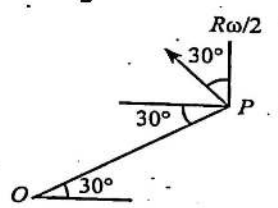
$\vec{V}_C-\vec{V}_A=(\vec{r}_C-\vec{r}_A)\times\vec{\omega}$

$=2\vec{r}_C\times\vec{\omega}=2(\vec{V}_C-\vec{V}_B)$

7. (a, b) Velocity at point O is

$v_0=(3R\omega)\hat{i}$

v_{PO} is $\frac{R\omega}{2}$ shown in figure. In vector form



$v_{PO}=-\frac{R\omega}{2}\sin30°\hat{i}+\frac{R\omega}{2}\cos30°\hat{k}$

$v_{PO}=-\frac{R\omega}{4}\hat{i}+\frac{\sqrt{3R\omega}}{4}\hat{k}$

Also, $v_{PO}=v_P-v_0$

$\therefore v_P=v_{PO}+v_0$

$=\left(-\frac{R\omega}{4}\hat{i}+\frac{\sqrt{3}R\omega}{4}\hat{K}\right)+3R\omega\hat{i}$

$=\frac{11}{4}R\omega\hat{i}+\frac{\sqrt{3}}{4}R\omega\hat{K}$

@FAKE CBSE NEET EDITION

8. [2] The torque acting on each of the points X, Y and Z are in anticlockwise direction and equal in magnitude.

$\tau_{total} = 3FR\sin 30^\circ = \frac{3FR}{2}$

Moment of inertia $I = \frac{MR^2}{2}$

$\therefore \tau_{total} = I\alpha = \frac{MR^2}{2}\alpha = \frac{3FR}{2}$

$\therefore \frac{1.5\times(0.5^2)}{2}\alpha = \frac{3\times 0.5\times 0.5}{2}$

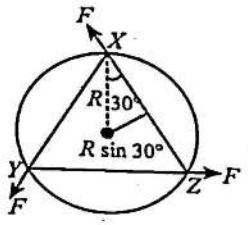
$\Rightarrow \alpha = 2$

From rotational kinematics equation

$\omega = \omega_0 + \alpha t$

At $t = 1\ s$

$\therefore\ \omega = 2t = 2\times 1 = 2\text{rad/s}$



9. We can choose any arbitrary directions of frictional forces at different contacts.

In the final answer the negative values will show the opposite directions.

Let f_1 = friction between plank and cylinder

f_2 = friction between cylinder and ground

a_1 = acceleration of plank

a_2 = acceleration of centre of mass of cylinder

and α = angular acceleration of cylinder about its CM.

Since, there is no slipping anywhere

$a_1 = 2a_2$

$a_1 = \frac{F - f_1}{m_2}$, $a_2 = \frac{f_1 + f_2}{m_1}$

$\alpha = \frac{(f_1 - f_2)R}{I} = \frac{(f_1 - f_2)R}{\frac{1}{2}m_1R^2}$, $\alpha = \frac{2(f_1 - f_2)}{m_1R}$,

$a_2 = R\alpha = \frac{2(f_1 - f_2)}{m_1}$

$a_1 = \frac{8F}{3m_1 + 8m_2}$ and $a_2 = \frac{4F}{3m_1 + 8m_2}$

$f_1 = \frac{3m_1F}{3m_1 + 8m_2}$ $f_2 = \frac{m_1F}{3m_1 + 8m_2}$

Since, all quantities are positive, they are correctly shown in figures.

10. Under the given condition only possibility is that friction is upward and it accelerated downwards as shown below:

The equation of motion are :

$a = \frac{mg\sin\theta - f}{m} = \frac{mg\sin 30^\circ - f}{m} = \frac{g}{2} - \frac{1}{m}$ ...(i)

$\alpha = \frac{\tau}{I} = \frac{fR^2}{I} = \frac{fR^2}{\frac{mR^2}{2}} = \frac{2f}{m}$ ...(ii)

For rolling

$a = R\alpha = 2f/m$

$\therefore \frac{3f}{m} = g/2$ or $f = mg/6$

11. $\left(\frac{M}{M+6m}\right)\omega_0$

The net angular momentum is conserved because there is no external force acting on the system

$I_1\omega_1 = I_2\omega_2$

$\therefore\ \omega_2 = \frac{I_1}{I_2}\cdot\omega_0$ (Given $\omega_1 = \omega_0$)

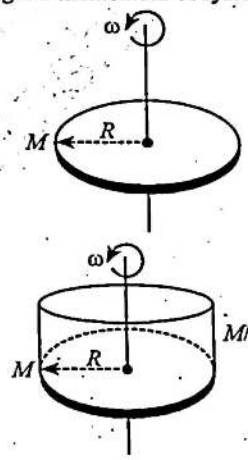
$\omega_2 = \frac{\frac{ML^2}{12}}{\left[\frac{ML^2}{12} + 2m\left(\frac{L}{2}\right)^2\right]}\omega_0$

$\omega_2 = \left(\frac{ML^2}{ML^2 + 6mL^2}\right)\omega_0$

$\omega_2 = \left(\frac{M}{M+6m}\right)\omega_0$

12. [False] Let initial angular momentum of system is L_i

Final angular momentum of system is L_f



Momentum inertia of disc of mass M is

$I_1 = \frac{1}{2}MR^2$

Momentum inertia of disc of mass $\frac{M}{4}$ is

$I_2 = \frac{1}{2}\times\frac{M}{4}\times R^2 = \frac{MR^2}{8}$

Final Moment of inertia of system

$I = I_1 + I_2 = \frac{5MR^2}{8}$

Eventually both will move with same angular velocity ω_2

When second disc is placed on first disc then,

$\tau_{ext} = 0$

Hence,

Angular momentum of the system is conserved

$L_f = L_i$

$I_1\omega_1 = I_2\omega_2$

$\omega_2 = \frac{I_1}{I}\omega$

$\omega_2 = \left[\frac{\frac{MR^2}{2}}{\frac{5MR^2}{8}}\right]\omega$

$\omega_2 = \frac{4}{5}\omega$

13. (a) The moment of inertia of the solid sphere is $I = 2mR^2/5$

Moment of inertia about an axis perpendicular to the plane of the disc $= mR^2/2$

Moment of inertia about a tangential axis is $= I = mr^2/2 + mr^2 = 3mr^2/2$

Since moment of inertia of both the objects are same, we have $3mr^2/2 = 2mR^2/5$

Solving, we get, $r = \frac{2}{\sqrt{15}}R$

14. (a) As we know that the moment of inertia of complete disc about a perpendicular axis passing through centre O is given as-

$I = \frac{1}{2}MR^2$

Whereas and are the mass and radius of the disc respectively.

Given that,

The mass of disc is and radius is .

Therefore,

$I_1 = \frac{1}{2}\times 9M\times R^2$

$I_1 = \frac{9}{2}MR^2$

Now, mass of cut out disc of radius $R/3$

$m = \frac{9M}{\pi R^2}\times(\pi)\left(\frac{R}{3}\right)^2$

$m = M$

Now using the theorem of parallel axis, the moment of inertia of cut out disc about the perpendicular axis passing through center O is,

@TAKE_CBSE_A @RAJ_EDUNET

$$I_2 = \frac{1}{2} \times M \times \left(\frac{R}{3}\right)^2 M\left(\frac{2R}{3}\right)^2$$

$$I_2 = \frac{1}{3}MR^2$$

Therefore, the moment of inertia of residue disc is-

$$I = I_1 - I_2$$

$$I = \frac{9}{2}MR^2 - \frac{1}{2}MR^2$$

$$I = 4MR^2$$

Hence the moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc passing through O is $4MR^2$.

15. (a) The MI of $\frac{3}{4}$th of the disc can be considered as difference of MI of the full disc and MI of $\frac{1}{4}$th of the disc.

Given, Mass of $\frac{3}{4}$th disc $= M$

Hence,

Mass of the full circular disc is

$$M' = \frac{4}{3}M$$

Let MI of the full disc be I_{full}

Let MI of one quarter of disc be $I_{quarter}$

Thus, MI of $\frac{3}{4}$th of disc:

$$I = I_{full} - I_{quarter}$$

$$I = I_{full} - \frac{1}{4}I_{full}$$

$$I = \frac{3}{4}I_{full}$$

$$I = \frac{3}{4}\left(\frac{1}{2}\left(\frac{4}{3}M\right)R^2\right)$$

$$I = \frac{1}{2}MR^2$$

16. (d) Moment of inertia about axis passing through center $= MR^2$

$$2\pi R = L, R = \frac{L}{2\pi}$$

About II' moment of inertia $= \frac{1}{2}MR^2$

About $XX' = \frac{1}{2}MR^2 + MR^2$

$$= \frac{3}{2}MR^2$$

Substituting value of R

Moment of inertia $= \frac{3}{2}M\left(\frac{L}{2\pi}\right)^2$

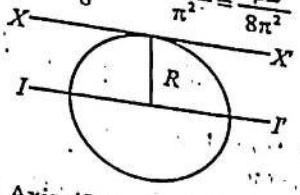
$$= \frac{3ML^2}{8\pi^2}$$

$$\rho = \frac{\text{mass}}{\text{volume}}$$

mass $M = \rho \times L$

Linear mass density $= \frac{\text{mass}}{\text{length}}$

$$= \frac{3\rho L \times L^2}{8} \times \frac{3\rho L^3}{\pi^2} = \frac{3\rho L^3}{8\pi^2}$$



17. (a) Axis AB is perpendicular to EF An axis passing through centre of square and perpendicular to the plane is

$$I_{GH} = I_{AB} + I_{EF}$$

$$I_{GH} = 2I_{AB} = 2I \text{ (as } I_{AB} = I_{EF})$$

By similar reason we can write

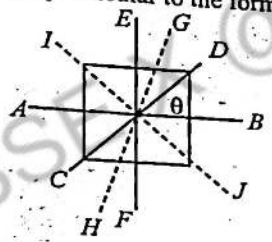
$$I_{GH} = I_{CD} + I_{IJ}$$

$$I_{GH} = 2I_{CD}$$

$$I_{CD} = \frac{2I}{2} = I$$

IJ is axis perpendicular to CD

The moment of inertia of a square plate about an axis on its plane is same about the axis which is also in same plane but perpendicular to the former



18. (c) Here it is given that the angular velocity is constant so the kinetic energy will be dependent only on the inertia and work done to rotate the rod will be dependent on the kinetic energy so indirectly the work done is dependent on the moment of inertia of the body. So, for the work to be done to be minimum the moment of inertia for the rod must be minimum.

Let us assume that the required point is OO. And from the given conditions we will draw a diagram which shows the exact condition which is given in the question. So, the diagram is as follows,

Given that the mass of the rod is negligible.

From the work energy theorem,

$W_{\text{all forces}} = \frac{1}{2}I\omega^2$, where ω is constant,

so the $W_{\text{all forces}}$ will be minimum when I will be minimum.

So now we will write the expression for the moment of inertia.

Let the point O is at the distance of x from one end, then the moment of inertia,

$$I = 0.3 \times (x)^2 + 0.7 \times (1.4 - x)^2$$

Now I is to be minimum so the differentiation will be zero for I to be minimum.

So, $\frac{dI}{dx} = 0$

$$\frac{d}{dx}[0.3 \times (x)^2 + 0.7 \times (1.4 - x)^2] = 0$$

$$\Rightarrow 0.3 \times 2x - 0.7 \times 2(1.4 - x) = 0$$

$$\Rightarrow 0.6x - (0.7 \times 2.8) + (0.7 \times 2x) = 0$$

$$\Rightarrow 0.6x - 1.96 + 1.4x = 0$$

$$\Rightarrow 2x = 1.96$$

$$\Rightarrow x = \frac{1.96}{2}$$

$$\Rightarrow x = 0.98\text{m}$$

So, the point on the rod through which the axis should pass in order that the work required for rotation of the rod is minimum is located at a distance of 0.98 m from the mass of 0.3 kg

Note:

Here we have seen the role of the work-energy theorem and we came to know that the work-energy theorem is useful in the analysing of the situations where a rigid body moves under several forces. The rigid body only possesses the kinetic energy since a rigid body cannot store a potential energy due to its rigid structure.

19. (a, b, c) Since, it is a square lamina

$I_3 = I_4$ and $I_1 = I_2$ (by symmetry)

From perpendicular axes theorem,

Moment of inertia about an axis perpendicular to square plate

and passing from O is

$$I = I_1 + I_3 = I_3 + I_4$$

$$I_0 = 2I_2 = 2I_3$$

or $I_2 = I_3$

Hence,

Rather we can say $I_1 = I_2 = I_3 = I_4$

Therefore, can be obtained by adding any two i.e. $I_0 = I_1 + I_2 + = I_1 + I_3$

$$= I_1 + I_4 = I_2 + I_3 = I_2 + I_4 = I_3 + I_4$$

20. [3] Given information

T = Total portion

R = Remaining portion and

C = Cavity

Let σ = mass per unit area.

@FAKE_CBSE @NU_EDUNET

Then,

$= \frac{\pi}{m}$

$m_c = \pi R^2\sigma$

For I_P

$I_R = I_T - I_C$

$= \frac{3}{2}m_T(2R)^2 - \left[\frac{1}{2}m_C R^2 + m_C r^2\right]$

$= \frac{3}{2}(4\pi R^2\sigma)(4R^2)$

$\left[\frac{1}{2}(\pi R^2\sigma) + (\pi R^2\sigma)(5R^2)\right] = 18.5\pi R^4\sigma$

For I_0

$I_R = I_T - I_C$

$= \frac{1}{2}m_T(2R)^2 - \frac{3}{2}m_C R^2$

$= \frac{1}{2}(4\pi R^2\sigma)(4R^2) - \frac{3}{2}(\pi R^2\sigma)R^2$

$= 6.5R4$

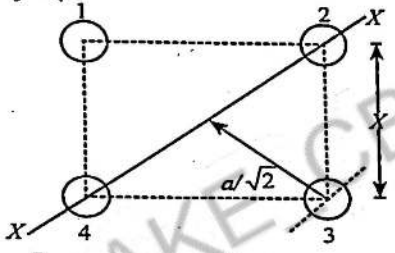
$\therefore \frac{I_P}{I_0} = \frac{18.5\pi R^2\sigma}{6.5\pi R^4\sigma} = 2.846$

Therefore, the nearest integer is 3.

21. [9] $r = \frac{d}{2} = \frac{\sqrt{5}}{2}\text{cm} = \frac{\sqrt{5}}{2}\times 10^{-2}$

$m \Rightarrow m = 0.5$ kg

$a = 4$ cm $= 4 \times 10^{-2}$ m $I_{xx} = I_1 + I_2 + I_3 + I_4$



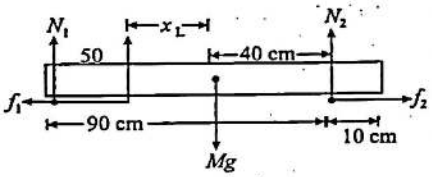
$= \left[\frac{2}{5}mr^2 + m\left(\frac{a}{\sqrt{2}}\right)^2\right] + \frac{2}{5}mr^2$

$+ \left[\frac{2}{5}mr^2 + m\left(\frac{a}{\sqrt{2}}\right)^2\right] + \frac{2}{5}mr^2$

Substituting the values, we get

$I_{xx} = 9\times 10^{-4}$ kg–m^2 $\therefore N = 9$

22.



Initially $N_1 + N_2 = mg$

Torque about center is zero that is

$N_1(50) = 40N_2 \Rightarrow 5N_1 = 4N_2$

Solving above equations we get

$N_1 = \frac{4Mg}{9}$ and $N_2 = \frac{5Mg}{9}$

Using definitions of kinetic and static frictions,

$f_{K_1} = 0.32N_1$, $f_{K_1} = 0.32N_2$

and $f_{L_1} = 0.4N_1$, $f_{L_2} = 0.4N_2$

Suppose x_L is the distance of left finger from centre when right finger starts moving. From rotational equilibrium condition

$N_1x_L = N_2(40)$

and $f_{K_1} = f_{L_2} \Rightarrow 0.32N_1 = 0.40N_2$

$\Rightarrow 4N_1 = 5N_2$

Therefore, $N_1x_L = \frac{4N_1}{5}(40)$ or $xL = 32$

Now xR = distance when right finger stops and left finger starts moving

Again, $N_1xL = N_2(xR)$

and $f_{L_1} = f_{K_2} \Rightarrow 0.4N_1 = 0.32N_2$

$\Rightarrow 5N_1 = 4N_2$

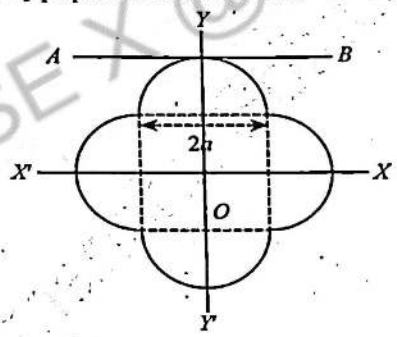
So, $\frac{4N_2}{5}(32) = N_2x_R$

$\Rightarrow x_R = \frac{128}{5} = 25.6$cm

23. Use perpendicular and parallel axis theorem

Given, $I_z = 1.6Ma^2$

By perpendicular axis theorem



$I_z = I_x + I_y$

and we know by symmetry $I_x = I_y$

$2I_x = I_z \qquad I_x = \frac{I_z}{2} = \frac{1.6Ma^2}{2} = 0.8Ma^2$

$I_{AB} = I_x + M(2a)^2 \Rightarrow I_{AB} = 0.8Ma^2 + 4Ma^2$

$\Rightarrow I_{AB} = 4.8Ma^2$

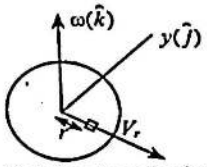
24. Angular momentum of the system about an axis perpendicular to plane of paper and passing through O will remain conserved.

$L_i = L_f \therefore mvL = I\omega;\ mvL$

$= \left(mL^2 + \frac{ML^2}{3}\right)\omega$

$\therefore \omega = \frac{3mv}{L(3m+M)}$

25. (*b*)



Rotation force is given by

$F_{rot} = F_{in} + 2m(v_{rot}\hat{i}) \times \omega t + m(\omega\hat{k} \times r\hat{i})$

$\times \omega\hat{k}mr\omega^2 r$

$F_{rot} = F_{in} + 2mv_{rot}\omega(-\hat{j}) + m\omega^2 r\hat{i}\ F_{in}$

$F_{rot} = F_{in} + 2mv_r\omega\hat{j}r = \frac{R}{4}[e^{\omega t} + e^{-\omega t}]\frac{d\theta}{dt}$

$v_r = \frac{R}{4}\left[e^{\omega t} + e^{-\omega t}\right]F_{in}$

$= 2m\frac{R\omega}{4}\left[e^{\omega t} + e^{-\omega t}\right]\omega\hat{j}F_{in}$

$= \frac{mR\omega^2}{2}\left[e^{\omega t} + e^{-\omega t}\right]\hat{j}$

We know that Also, reaction is due to disc surface so,

$F_{reaction} = \frac{mR\omega^2}{2}\left[e^{\omega t} - e^{-\omega t}\right]\hat{j} + mg\hat{k}$

26. (*b*) $|L|$ or $L = I\omega$ (around the axis of rod)

$I = I_{rod} + mx^2 = I_{rod} + mv^2t^2$

where m = mass of insect

We know that angular momentum is

$\therefore L = (I_{rod} + mv^2t^2)\omega$ Now $|\tau| = \frac{dL}{dt}$

$= (2mv^2\, t\omega)$ or $|\tau| \propto t$

i.e. the graph is a straight line passing through origin.

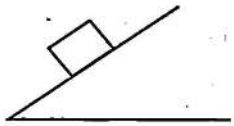
After time T, L= constant

$\therefore |\tau| \text{ or } \frac{dL}{dt} = 0$

Note:

If we were given that the particle was moving with a constant velocity or angular momentum, then its radius will also change but as that is not the case here, we will not assume that. Also, as it is only given that speed reduces, we have considered that it does not go in a negative direction, if that happens the direction of angular momentum must change.

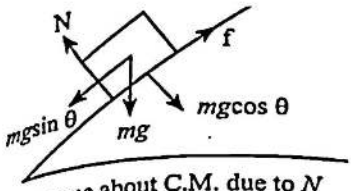
27. (*b*)



At $\theta = 60°$, block on verge of slipping

At angle $\theta < 60°$

@FAKE CBSE X @RAJ EDUNET



torque about C.M. due to N

$\tau_N = N \times (0.05) = mg\cos\theta$

$r_N = N \times (0.05) = mg\cos\theta\,(0.05)$ Torque about C.M. due to f

$\tau_f = mg\sin\theta \times (0.75)$

$= mg\sin\theta\,(0.075)$

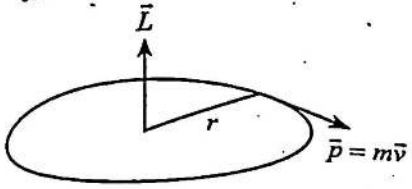
If $\tau_f > \tau_N$ then block will topple for line

$mg\cos\theta(0.05) < mg\sin\theta(0.075)$

$\tan\theta > \frac{0.05}{0.075}$; $\tan\theta > \frac{2}{3}$

So, the block will remain at rest on the plane up to certain θ and then it will topple

8. (a) Torque will be zero about that point because force will pass through the centre of the circle.

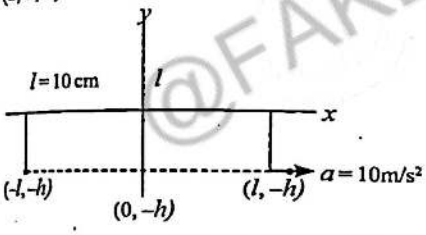


9. (c) For minimum force for toppling, the normal should pass through point A Balancing torque about the point A, for minimum F:

$FL \geq mg \times \frac{L}{2}$

so the minimum force is $\frac{mg}{2}$

10. (a, b, c)



Force acting along X-axis ma = 0.2 × 10 =2 N

Distance covered in 2 s along X-axis

$= \frac{1}{2}at^2 = \frac{1}{2} \times 10 \times 4 = 20\text{m} = 2l$

Particle reaches at the point $(l,-h)$ at t = 2s (Option (a) is correct

τ at $(l,-h)$ $Fh = 2 \times 1 = 2\text{Nm}$

$\vec{\tau} = 2(\hat{k})$ (Option (b) is correct)

$v(t=2s)$ $10 \times 2 = 20$ m/s

$\vec{L}$ | at $(l,-h) = mvh = 0.2 \times 20 \times 1$ $= 4$ kgm²/s

$\vec{L} = 4(\hat{k})$ (Option (c) is correct)

τ at $(0,-h) = Fh = 2 \times 1 = 2\text{Nm}$

$\vec{\tau} = 2(\hat{k})$ (Option (d) is incorrect)

31. (a, c) $\vec{F} = (\alpha t)_1 + \beta\hat{j}$ $[t=0, v=0, \vec{r}=\vec{0}]$

$\alpha = 1, \beta = 1$; $\vec{F} = t\hat{i} + \hat{j}$

$m\frac{d\vec{v}}{dt} = t\hat{i} + \hat{j}$

by integration we get

$m\vec{v} = \frac{t^2}{2}\hat{i} + f\hat{j}$ $[m = 1kg]$

$\frac{d\vec{r}}{dt} = \frac{t^2}{2}\hat{i} + t\hat{j}$ $\left[\vec{r} = \vec{0} \text{ at } t = 0\right]$

On integrating we get

$\vec{r} = \frac{t^3}{6}\hat{i} + \frac{t^2}{2}\hat{j}$

At $t = 1sec, \vec{\tau} = (\vec{r} \times \vec{F})$

$= \left(\frac{1}{6}\hat{i} + \frac{1}{2}\hat{j}\right) \times (\hat{i} + \hat{j})$

$\vec{\tau} = -\frac{1}{3}\hat{k}$, $\vec{v} = \frac{t^2}{2}\hat{i} + t\,\hat{j}$

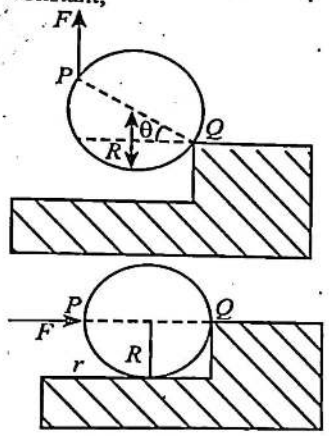
$t = 1\vec{v} = \left(\frac{1}{2}\hat{i} + \hat{j}\right) = \frac{1}{2}\left(i + 2\hat{j}\right)$ m / sec

At $t = 1; \vec{s} = \vec{r_1} - \vec{r_0} = \left[\frac{\hat{i}}{6} + \frac{\hat{j}}{2}\right] - \left[\vec{0}\right]\vec{s}$

$= \frac{1}{6}\hat{i} + \frac{1}{2}\hat{j}$

$|\vec{s}| = \sqrt{\left(\frac{1}{6}\right)^2 + \left(\frac{1}{2}\right)^2} \Rightarrow \frac{\sqrt{10}}{6}m$

32. (a,c) Assuming that the force behaves as depicted and that its direction remains constant,



$\tau_{net} = F(2R\cos\theta) - mgR\cos\theta$

$\tau_{net} = R\cos\theta(2F - mg)$

Which definitely infers that as θ increases, τ_{net} decreases.

When force is applied as depicted, frictional force is created between the bottom point and the horizontal surface, resulting in a non-zero torque around point Q.

33. (a, c, d) From the figure,

$x = \frac{L}{2}Sin\theta \Rightarrow Sin\theta = \frac{x}{\left(\frac{L}{2}\right)}$ ...(i)

$y = LCos\theta \Rightarrow Cos\theta = \frac{y}{L}$ ...(ii)

Squaring and adding equations (i) and (ii), we have

$sin^2\theta + cos^2\theta = \frac{x^2}{\left(\frac{L}{2}\right)^2} + \frac{y^2}{L^2}$

$\Rightarrow \frac{x^2}{\left(\frac{L}{2}\right)^2} + \frac{y^2}{L^2} = 1$

This the equation of an Ellipse. Hence, the trajectory of the point A is elliptical.

From the figure, Instantaneous Torque about the point of contact is given as:

$\tau = mg \times \frac{L}{2}Sin\theta$

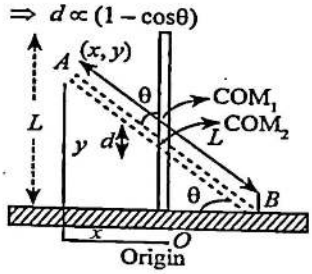
$\tau \propto \text{Sin}\theta$

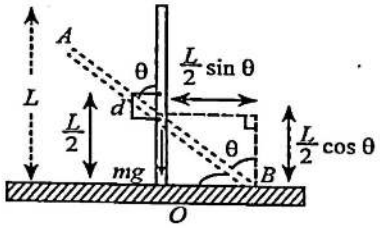
Since, there is no horizontal force on rod during its motion. ⇒ Center of Mass will fall vertically downwards.

From the figure, displacement d of the mid point is given as:

$d = \frac{L}{2} - \frac{L\cos\theta}{2} = \frac{L}{2}(1 - cos\theta)$

$\Rightarrow d \propto (1 - \cos\theta)$





34. (a, b, c) Torque $\vec{\tau} = \frac{d\vec{L}}{dt}$ where L is angular momentum.

$\vec{\tau} = \vec{A} \times \vec{L}$

Taking dot product on either side with

@FAKE_CBSE_TOPPER_RAJ_BHAI_NET

$\vec{L}.\frac{d\vec{L}}{dt}=0$

$\vec{L}.d\vec{L}=0$

$d\vec{L}=0$

Magnitude of $\vec{L}$ thus remains constant.

Let the component of $\vec{L}$ in the direction of $\vec{A}$ be $\vec{L}_{\parallel}$ and perpendicular to $\vec{A}$ be $\vec{L}_{\perp}$.

$$\frac{d\left(L_{\parallel}+L_{\perp}\right)}{dt}=\vec{A}\times\left(L_{\parallel}+L\perp\right)$$

So, $\frac{dl_{\parallel}}{dt}=\vec{A}\times\vec{L}_{\parallel}=0$

Hence $\vec{L}_{\parallel}$ that is component of $\vec{L}$ in the direction of $\vec{A}$ is always constant.

35. (*a*) If force $F=0\Rightarrow$ potential energy $U=$ constant $F\neq 0\Rightarrow$ force is conservative $\Rightarrow$ Total energy $E=$ constant List-I

$(P)\ r(t)=\alpha t\hat{i}+\beta t\hat{j}$

$\frac{dr}{dt}=v=\alpha\hat{i}+\beta\hat{j}=$ constant

$\Rightarrow p=$ constant

So, magnitude of velocity

$|v|=\sqrt{\alpha^2+\beta^2}=$ constant

$\Rightarrow K=$ constant

$\frac{dV}{dt}=a=0\Rightarrow F=0\Rightarrow U=$ constant

Total energy is given by

$E=U+K=$ constant

$L=m(r\times v)=0$

$L=$ constant

P $\rightarrow$ 1,2,3,4,5 $(Q)\ r(t)$

$\alpha\cos\omega t\hat{i}+\beta\sin\omega t\hat{j}(Q)$

$r(t)=\alpha\cos\omega t\hat{i}+\beta\sin\omega t\hat{j}\ \frac{dr}{dt}=v$

$=\alpha\omega\sin\omega t(-\hat{i})+\beta\cos\omega t\,\hat{j}\neq$ constant

$\Rightarrow P\neq$ constant

$\Rightarrow p\neq$ constant

$|v|=\omega\sqrt{(\alpha sin\omega t)^2+(\beta cos\omega t)^2}$

$\neq$ constant

$\Rightarrow K\neq$ constant

$a=\frac{dv}{dt}=-\omega^2 r\neq 0$

$\Rightarrow E=$ constant $=K+U$

But $K\neq$ constant $\Rightarrow U\neq$ constant

$L=m(r\times v)=m\omega\alpha\beta\,(\hat{k})=$ constant

$Q\rightarrow 2,5$

$(R)\ r(t)=\alpha\,(\cos\omega\hat{i}+\sin\omega t\hat{j})$

$\frac{dr}{dt}=v=\alpha\omega[\sin\omega t(-\hat{i})+\cos\omega\hat{t}\hat{j}]\neq$ constant

$\Rightarrow p\neq$ constant

$|v|=\alpha\omega=$ constant $\Rightarrow K=$ constant

$a=\frac{dv}{dt}=-\omega^2 r\neq 0\Rightarrow E=$ constant,

$U=$ constant

$L=m(r\times v)=m\omega\alpha^2\hat{k}=$ constant

$R\rightarrow 2,3,4,5\ r(t)=\alpha t\hat{i}+\frac{\beta}{2}t^2\hat{j}$

$(S)\ \frac{dr}{dt}=v=\alpha\hat{i}+\beta\hat{j}\neq$ constant

$\Rightarrow P\neq$ constant

$\hat{v}=\sqrt{\alpha^2+(\beta t)^2}\neq$ constant

$\Rightarrow K\neq$ constant

$a=\frac{dv}{dt}=\beta\hat{j}\neq 0\Rightarrow E=$ constant

$=K+U$

But $K\neq$ constant

$\Rightarrow U\neq$ constant

$L=m(r\times v)=\frac{1}{2}\alpha\beta t^2\hat{k}\neq$ constant

$S\rightarrow 5$

36. [4] Assume the friction between surface and sphere be f_s

Take the friction between stick and sphere be f_a and assume the N be the normal reaction between sphere and stick

Now according to Newton's laws of motion

$N-f_s=2N,$

$f_s=1.4N$

Taking torque about center, we get

$(f_s-f_a)r=I\alpha$

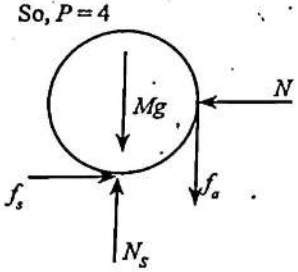
$a=\alpha r$ and $I=mr^2$

on solving

$f_a=0.8=\mu N$

$\mu=0.4=\frac{4}{10}$

So, $P=4$

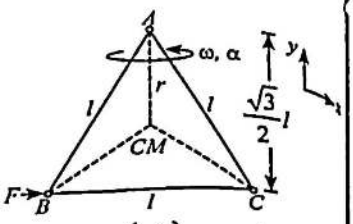


37. (*a*) The distance from centre of mass (CM) of the system about point A will be

$r=\frac{l}{\sqrt{3}}$

So, the magnitude of horizontal force applied by the hinge on the body is

$F=$ centripetal force or $F=(3m)r\omega^2$



or $F=(3m)\left(\frac{l}{\sqrt{3}}\right)\omega^2$

or $F=\sqrt{3}ml\omega^2$

(*b*) Angular acceleration of system about point A is

$\alpha=\frac{\tau_A}{I_A}=\frac{(F)\left(\frac{\sqrt{3}}{2}l\right)}{2ml^2}=\frac{\sqrt{3}F}{4ml}$

Also, acceleration of CM along x-axis is

$a_x=r\alpha=\left(\frac{l}{\sqrt{3}}\right)\left(\frac{\sqrt{3}F}{4ml}\right)$

or $a_x=\frac{F}{4m}$

Let F_x be the force applied by the hinge along X-axis.

Then, $F_x+F=(3m)a_x$

or $F_x\neq F=(3m)\left(\frac{F}{4m}\right)$

or $F_x+F=\frac{3}{4}F$

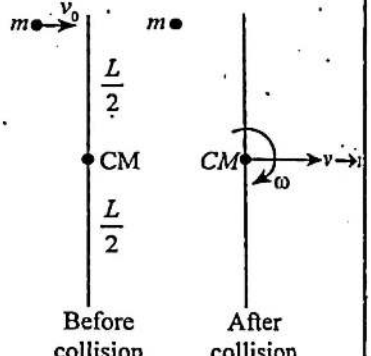
or $F_x=-\frac{F}{4}$

Hence if F_y be the force applied by the hinge along $Y=$ axis. Then,

$F_y=$ centripetal force

$F_y=\sqrt{3}ml\omega^2$

38. (*a*) In the case just after collision, take velocity of CM of rod is v and angular velocity about CM is ω. Using the following three laws.



(1) External force on the system (rod + mass) in horizontal plane along x-axis is zero.

@FAKE_CBSE_@RAJEDUNET

∴ Applying conservation of linear momentum in x-direction.

$mv_0 = mv$ ...(i)

(2) Net torque on the system about CM of rod is zero.

∴ Applying conservation of angular momentum about CM of rod, we get $mv_0\left(\frac{L}{2}\right) = I\omega$

or $mv_0\frac{L}{2} = \frac{ML^2}{12}\omega$

or $mv_0 = \frac{ML\omega}{6}$ ...(ii)

(3) Since, the collision is elastic, kinetic energy is also conserved.

$\therefore \frac{1}{2}mv_0^2 = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$

or $mv_0^2 = Mv^2 + \frac{ML^2}{12}\omega^2$ ...(iii)

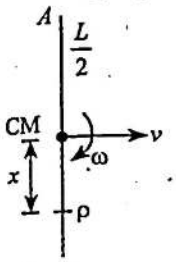
From Eqs. (i), (ii) and (iii), we get the following results

$\frac{m}{M} = \frac{1}{4}$ $v = \frac{mv_0}{M}$ and $\omega = \frac{6mv_0}{ML}$

(b) Point P will be at rest if $x\omega = v$

or $x = \frac{v}{\omega} = \frac{mv_0/M}{6mv_0/ML}$ or $x = L/6$

$\therefore AP = \frac{L}{2} + \frac{L}{6}$ or $AP = \frac{2}{3}L$



(c) After time

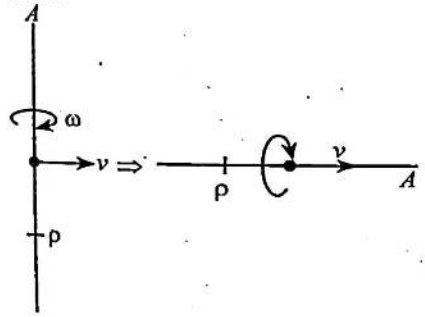
$t = \frac{\pi L}{3v_0}$

angle rotated by rod,

$\theta = \omega t = \frac{6mv_0}{ML}\cdot\frac{\pi L}{3v_0}$

$= 2\pi\left(\frac{m}{M}\right) = 2\pi\left(\frac{1}{4}\right) \therefore \theta = \frac{\pi}{2}$

Therefore, situation will be as shown below

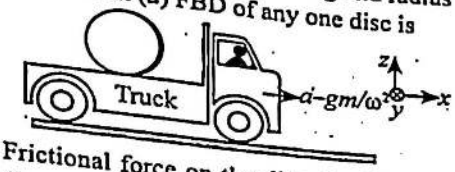


∴ Resultant velocity of point P will be

$|v_P| = \sqrt{2}v = \sqrt{2}\left(\frac{m}{M}\right)v_0$

$= \frac{\sqrt{2}}{4}v_0 = \frac{v_0}{2\sqrt{2}}$ or $|v_P| = \frac{v_0}{2\sqrt{2}}$

39. Given, mass of disc $m = 2$ kg and radius $R = 0.1$ m (a) FBD of any one disc is



Frictional force on the disc should be in forward direction.

Let a_0 be the linear acceleration of CM of disc and α the angular acceleration about its CM. Then,

$a_0 = \frac{f}{m} = \frac{f}{2}$ $\alpha = \frac{\tau}{I} = \frac{fR}{\frac{1}{2}mR^2} = \frac{2f}{mR} = \frac{2f}{2\times 0.1} = 10f$

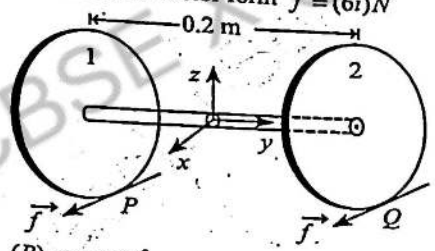
Since, there is no slipping between disc and truck. Therefore,

$\therefore \alpha_0 + R\alpha = a$ or $\left(\frac{f}{2}\right) + (0.1)(10f) = a$

or $\frac{3}{2}f = a \Rightarrow f = \frac{2a}{3} = \frac{2\times 9.0}{3}N$ $\therefore f = 6N$

Since, this force is acting in positive x-direction.

Therefore, in vector form $f = (6\hat{i})N$



(B) $\tau = r \times f$

Here, $f = (6\hat{i})N$ (for both the discs)

$r_P = r_1 = -0.1\,\hat{j} - 0.1\,\hat{k}$ $r_Q = r_2$

$= 0.1\,\hat{j} - 0.1\,\hat{k}$

Therefore, frictional torque on disk 1 about point O (centre of mass).

$\tau_1 = r_1 \times f = (-0.1\,\hat{j} - 0.1\,\hat{k}) \times (6\,\hat{i})N - m$

$= (0.6\hat{k} - 0.6\hat{j})$

or

and $|\tau_1| = \sqrt{(0.6)^2 + (0.6)^2} = 0.85\,N - m$

Similarly, $\tau_2 = r_2 \times f = 06\,(-\hat{j} - \hat{k})$

and $|\tau_1| = |\tau_2| = 0.85$ Nm

40. (a) Angular momentum of the system (rod + insect) about the centre of the rod O will remain conserved just before collision and after collision i.e., $K_i = K_f$

or $MV\frac{1}{4} = I\omega = \left[\frac{ML^2}{12} + M\left(\frac{L}{4}\right)^2\right]\omega$

or $MV\frac{1}{4} = \frac{7}{28}ML^2\omega$

i.e., $\omega = \frac{12}{7}\frac{V}{L}$ ...(i)

(b) Due to the torque of weight of insect about O, angular momentum of the system will not remain conserved (although angular velocity w is constant). As the insect moves towards B, moment of inertia of the system increases, hence, the angular momentum of the system will increase.

Let at time t_1 the insect be at a distance x from O and by then the rod has rotated through an angle q. Then, angular momentum at that moment,

$K = \left[\frac{ML^2}{12} + Mx^2\right]\omega$

Hence,

$\frac{dK}{dt} = 2M\omega x\frac{dx}{dt}$ $(\omega = \text{constant})$

$\Rightarrow \tau = 2M\omega x.\frac{dx}{dt}\left(\frac{dK}{dt} = \tau\right)$

$\Rightarrow Mgx\cos\theta = 2M\omega x\frac{dx}{dt}$

$\Rightarrow dx = \left(\frac{g}{2\omega}\right)\cos\omega t\,dt$ $(\theta = \omega t)$

At time $t = 0$, $x = \frac{L}{4}$ and at time $t = \frac{T}{4}$

or $\frac{\pi}{2\omega}$, $x = \frac{L}{2}$

41. $\frac{M\omega^2 AR}{2}$

The cylinder has a fixed axis, so it can perform rotational motion only.

$f\,R = \frac{MR^2}{2}\alpha$

$f = \frac{MR}{2}\alpha$

For no slipping,

$R\alpha$ acceleration of the platform

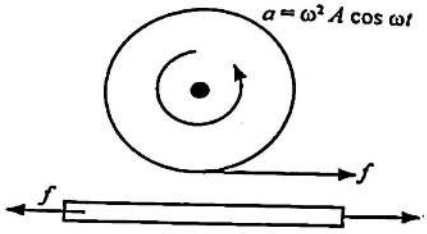
$f_{max} = \frac{M\omega^2 A}{2}$

For the maximum torque, f would be maximum and

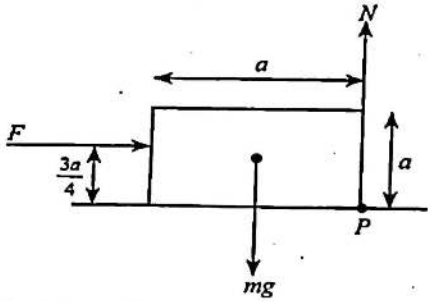
$\tau_{max} = f_{max} \times R = \frac{M\omega^2 AR}{2}$

So the maximum torque,

@FAKE_CBSE_X@RAJ_EDUNET



42. As the condition just begins to tilt, the normal reaction of the cube will shift to its edge as shown.
(Figure shows the situation when the cube is just about to tilt)

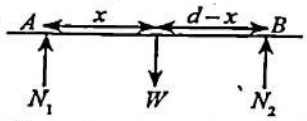


At this condition, net torque about point $P = 0$ (for minimum force F)

i.e $F \times \left(\frac{3a}{4}\right) = mg \times \left(\frac{a}{2}\right)$

$\therefore F = \frac{2mg}{3}$

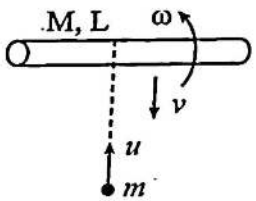
43.



Given situation is shown in figure.
N_1 = Normal reaction on A
N_2 = Normal reaction on B
W = Weight of the rod
In vertical equilibrium,
$N_1 + N_2 = W$ ...(i)
Torque balance about the centre of mass of the rod,
$N_1 x = N_2 (d-x)$
Putting value of N_2 from equation (i)
$N_1 x = (W - N_1)(d-x) \Rightarrow N_1 x = Wd - Wx - N_1 d + N_1 x \Rightarrow N_1 d = W(d-x)$

$\therefore N_1 = \frac{W(d-x)}{d}$ and for $N_2 = \frac{W(x)}{d}$

44. (a)



Applying the conservation of angular momentum about hinge,

$$mu\frac{L}{2} + 0 = -mv\frac{L}{2} + \frac{ML^2}{3}\omega$$

$$0.1 \times 5 \times 0.1 = -0.1 \times v \times 0.1 + \frac{1 \times (0.2)^2}{3}\omega$$

$$\Rightarrow \omega = (5 + v) \times \frac{3}{4} \quad ...(i)$$

Also from eq. of restitution

$$e = 1 = \frac{\omega\frac{L}{2} + V}{u} \Rightarrow u = \omega\frac{L}{2} + V$$

$$\Rightarrow 5 = \omega \times 0.1 + v$$

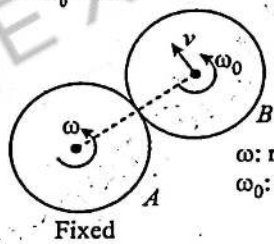
$$\Rightarrow v = 5 - 0.1\,\omega \quad ...(ii)$$

From (i),

$$\omega = 5 \times \frac{3}{4} + \frac{3}{4}(5 - 0.1\omega)$$

$\omega \approx 6.98$ rad/sec
From (ii), $v = 4{:}30$ m/s
Hence option (a)

45. (b) If the linear velocity of center of mass of disc B is v, then
$v = \omega (2R)$
Further, since the disc B is rolling without slipping,
$v = \omega_0 R$: no slipping
$\therefore \omega_0 = 2\omega$



ω: revolution
ω_0: rotation

$$\vec{L} = m\vec{r} \times \vec{v}_c + I_c\omega_0 = M^2Rv + \frac{1}{2}MR^2\omega_0.$$

$$= 4MR^2\omega + \frac{1}{2}MR^2(2\omega) = 5MR^2\omega$$

$\therefore n = 5$

46. (c) Here, the height of the cone $h >> r$
So, $\mu N = mg$

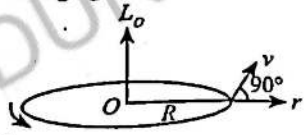
$$\mu m(R-r)\omega_0^2 = mg; \quad \omega_0 = \sqrt{\frac{g}{\mu(R-r)}}$$

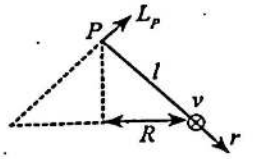
47. (d) Assume the other mass at the instant is heated at a distance of x from the centre O.
By law of conservation of angular momentum, we have
$I_1\omega_1 = I_2\omega_2$
$\therefore (MR^2)(\omega)$

$$= \left[MR^2 + \frac{M}{8}\left(\frac{3}{5}R\right)^2 + \frac{M}{8}x^2\right]\left(\frac{8}{9}\omega\right)$$

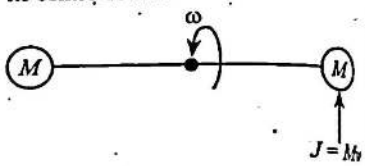
On solving, we get $x = \frac{4}{5}R$

48. (c) Angular momentum of a particle about a point is defined by $L = r \times P$
$= m(r \times v)$
Taking L_0
$|L| = (mvr\sin\theta) = m(R\omega)(R)\sin 90° = \text{constant}$
Direction of L_0 is on upwards. So, whole L_0 is constant, both in magnitude and direction.
For L_p
$|L_p| = (mvr\sin\theta) = (m)(R\omega)(l)\sin 90° = (mRl\omega))$
Magnitude of L_p will remain constant but direction of L_p will keep on changing.



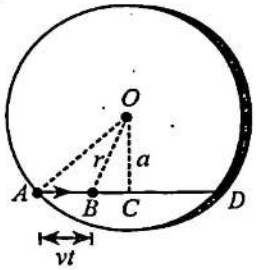


49. (a) Given system of balls will rotate about its centre of mass.



initial angular momentum = $Mv(L/2)$
Final angular momentum
$= I\omega = 2M(L/2)^2\omega$
by conservation of angular momentum,
$MV(L/2) = 2M(L/2)^2\,\omega$ So $\omega = (V/L)$

50. (b) Angular momentum will remain conserved because there is no external torque.



@FAKE_CBSE_@RAJ_EDUNET

When a tortoise moves from A to C the moment of inertia will decrease and then increase as it moves from C and D. Therefore, (0 will initially increase and then decrease.

Let R be the radius of the platform, m the mass of the disc and M is the mass of the platform.

Moment of inertia when the tortoise is at A

$$I_1 = mR^2 + \frac{MR^2}{2}$$

Moment of inertia when the tortoise is at B

$$I_2 = mr^2 + \frac{MR^2}{2}$$

Here, $r^2 = a^2 + \left[\sqrt{R^2 - a^2} - vt\right]^2$

From conservation of angular momentum

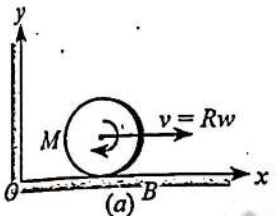
$\omega_0 I_1 = \omega(t) I_2$

Putting the values we can see that variation of is non-linear and smooth (differentiable).

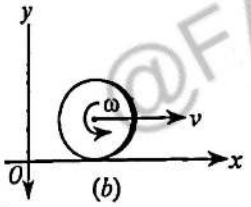
51. (b) Angular momentum is conserved or constant as the net external torque on the system is zero.

The total mechanical energy of the system is also conserved due to the conservative force acting on the system.

52. (c) From the theorem



(a)



(b)

$L_0 = L_{CM} + M(r \times v)$ ...(i)

We may write

Angular momentum about Origin = Angular momentum about CM + Angular momentum of CM about origin

$\therefore L_0 = I\omega + MRv$

$$L_0 = \frac{1}{2}MR^2 + MR(R\omega)$$

$$L_0 = \frac{3}{2}MR^2\omega$$

NOTE:

In this case [Figure (a)] both the terms in Eq. (i),

i.e. L_{CM} and $M(r \times v)$ have the same direction A.

That is why, we have used $L_0 = I\omega + MRv$

We will use $L_0 = I\omega - MRv$ If they are in the opposite direction as shown in figure (b).

53. (a) When the block hits the ridge O, it will start rotating about an axis passing through O and perpendicular to the plane of the paper. Net torque about O is zero, therefore, angular momentum L about O will be conserved.

$$L_i = L_f \ \therefore Mv\left(\frac{a}{2}\right) = I_O\omega = (I_{cm} + Mr^2)$$

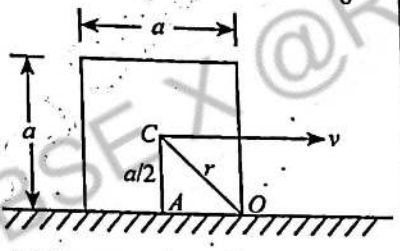
$$\omega = \left(\frac{Ma^2}{6} + M\left(\frac{a}{\sqrt{2}}\right)^2\right)\omega = \frac{2}{3}Ma^2\omega$$

where I_0 is the MI of the cube about point O and ω is the angular speed of rotation of the block about O.

$$\therefore \omega = \frac{3v}{4a}$$

Note: The MI of a square plate is $\frac{Ma^2}{6}$.

Hence, MI of a cube will be also $\frac{Ma^2}{6}$.



54. (b) Angular momentum of mass m moving with a constant velocity about origin is given as in the figure.

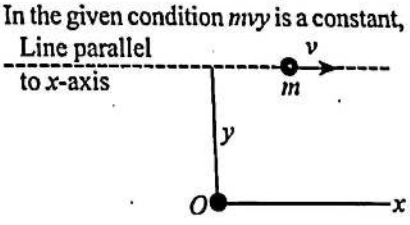
By formula : $\vec{L} = \vec{r} \times \vec{P}$

Direction is given by right hand thumb rule which is coming along -z axis

Magnitude of L = |momentum| |perpendicular distance of line of action of the momentum from origin|

$L = mvy$

In the given condition mvy is a constant,

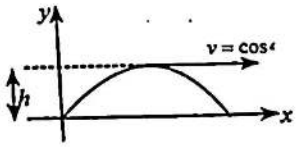


55. (b) Angular momentum of mass moving with a constant velocity about point of projection is given as in the figure.

By formula : $\vec{L} = \vec{r} \times \vec{P}$

Magnitude of L = |momentum| |perpendicular distance of line of action of the momentum from origin|

$$r_{perp} = h = \frac{v^2 \sin^2 45°}{2g} = \frac{v^2}{4g}$$



Here,

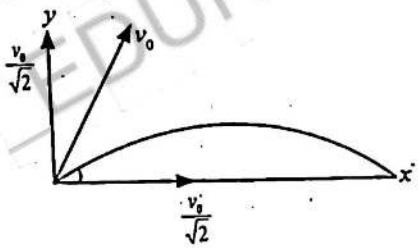
$$L = m\frac{v}{\sqrt{2}}h$$

$$\therefore \ L = m\frac{v}{\sqrt{2}}h\left(\frac{v^2}{4g}\right) = \frac{mv^2}{4\sqrt{2}g}$$

56. (b) X-axis along the horizontal

Y-axis along the vertically upwards direction as shown in below figure.

For the horizontal motion during the time 0 to t,



$$u_x = v_0\cos 45° = \frac{v^0}{\sqrt{2}}$$

$$X = u_x t = \frac{v_0}{\sqrt{2}}\frac{v_0}{g}$$

For the vertical motion

$$u_y = v_0\cos 45° - gt$$

$$u_y = \frac{v_0}{\sqrt{2}} - \frac{v_0}{g}g$$

$$u_y = \frac{\left(1-\sqrt{2}\right)v_0}{\sqrt{2}}$$

$$y = \left(v_0 \sin 45°\right)t - \frac{1}{2}gt^2$$

$$y = \frac{v_0^2}{\sqrt{2}g} - \frac{v_0^2}{2g} = v_0^2\left(\sqrt{2}-1\right)$$

Angular momentum of the particle is

$$L = \vec{r} \times \vec{P}$$

$$L = m\,\vec{r} \times \vec{v}$$

$$L = m\left(i\overline{X} \times j\overline{Y}\right) \times \left(i\overline{V}_x \times j\overline{V}_y\right)$$

$$L = m\left(K_x\overline{V}_x \times K_y j\overline{V}_y\right)$$

@FAKE_CBSE_X @RAJ_EDUNET

$$L = m\bar{k}\left[\left(\frac{v_0^2}{\sqrt{2}}\right)\frac{v_0}{g}(1-\sqrt{2}) - \frac{v_0^2}{2g}(\sqrt{2}-1)\frac{v_0}{\sqrt{2}}\right]$$

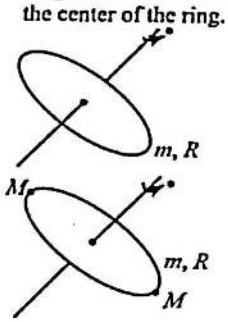
$$L = -k\left[\frac{mv_0^3}{2\sqrt{2}g}\right]$$

Hence,

The angular momentum of the particle is $\frac{mv_0^3}{2\sqrt{2}g}$.

57. *(c)* Let the final angular velocity be w'.

Angular momentum is conserved about the center of the ring.



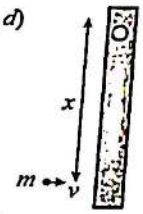
$L_i = L_f$

$I\omega + 0 = I\omega' + 2 \times mr^2\omega'$

$Mr^2\omega + 0 = Mr^2\omega' + mr2\omega'$

$$\omega' = \frac{M\omega}{M+2m}$$

58. *(a, c, d)*



By the angular momentum conservation about the suspension point.

$$mvx = \left(\frac{mL^2}{3} + mx^2\right)\omega$$

$$\therefore \ \omega = \frac{mvx}{\frac{mL^2}{3} + mx^2} = \frac{3vx}{L^2 + 3x^2}$$

For maximum $\omega \Rightarrow \frac{d\omega}{dx} = 0$

$$\therefore \ x_M = \frac{L}{\sqrt{3}}$$

Putting the above value in ω expression, we get

$$\omega = \frac{v}{2L}\sqrt{3}$$

59. *(b, c)* Given potential energy $V = \frac{kr^2}{2}$

$F = -kr$ (towards centre) $\left[F = -\frac{dV}{dr}\right]$

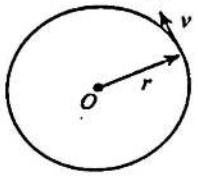
At $r = R$,

$kR = \frac{mv^2}{R}$ [Centripetal force]

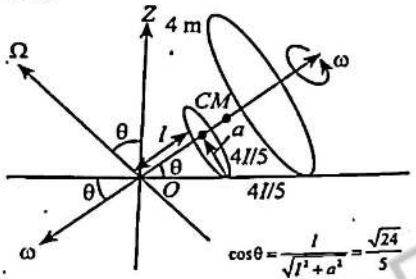
where v is the speed of the particle

$\Rightarrow$ velocity $v = \sqrt{\frac{kR^2}{m}} = \sqrt{\frac{k}{m}}R$

$L = mvR = m\sqrt{\frac{k}{m}}R^2$,



60. *(c,d)*



$$\cos\theta = \frac{l}{\sqrt{l^2+a^2}} = \frac{\sqrt{24}}{5}$$

(a) $L_z = L_{CM-O}\cos\theta - L_{D-CM}\sin\theta$

$$= \frac{81\sqrt{24}}{5}a^2m\omega \times \frac{\sqrt{24}}{5} - \frac{17ma^2\omega}{2} \times \frac{1}{\sqrt{24}}$$

$$= \frac{81 \times 24ma^2\omega}{25} - \frac{17ma^2\omega}{2\sqrt{24}}$$

(b) $L_{CM-O} = (5m)\left[\frac{9l}{5}\omega\right]\frac{9l}{5} = \frac{81ml^2\omega}{5}$

$$= \frac{81ml^2}{5} \times \frac{a\omega}{l} \ \therefore L_{CM-O} = \frac{81mla\omega}{5}$$

$$= \frac{81\sqrt{24}a^2m\omega}{5}$$

(c) Velocity of point P : $a\omega = 1\omega$ then

$\omega = \frac{a\omega}{1}$ = Angular velocity of *C.M.* w.r.t. point *O*.

Angular velocity of *CM* w.r.t. *Z*-axis $= \omega_0 \cos\theta$

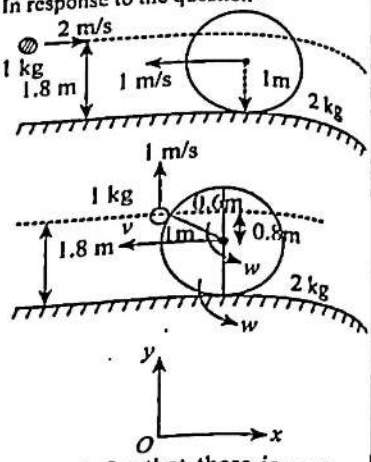
$$\omega_{CM-z} = \frac{a\omega}{1}\frac{\sqrt{24}}{5} = \frac{a\omega}{\sqrt{24}a}\frac{\sqrt{24}}{5}$$

$$\omega_{CM-z} = \frac{\omega}{5}$$

(d) $L_{D-cM} = \frac{ma^2}{2}\omega + \frac{4m(2a)^2}{2}\omega = \frac{17ma^2\omega}{2}$

61. *(a,c)* Assume the ring's center of mass has a velocity of v and an angular speed of angular speed about an axis through its center of mass of angular speed of

In response to the question -



We can infer that there is no friction between the ring and the ground because the ring is rolling without slipping before colliding, hence there is no net force acting on the system.

The application of the Law of Conservation of Linear Momentum along the *x*-axis

$P_i = P_f$

$1 \times 2 - 2 \times 1 = 1 \times 0 - 2 \times v$

$v = 0$

Take the instantaneous axis of rotation at contact point *P*. If friction is present, the torque around that location will be zero.

The application of the angular momentum conservation law.

$\vec{L}_i = \vec{L}_f$

Taking the anti-clockwise direction as positive,

$L_i = L_{ball} + L_{ring} = mvr_\perp + I\omega$

$L_i = -1 \times 2 \times 1.8 + (2 \times 2 \times 1^2) \times 1$

[perpendicular distance of ball from MO = 0.6m]

$\vec{L}_i = \vec{L}_f$

$= -1 \times 2 \times 1.8 + (2 \times 2 \times 1^2) \times 1$

$= -1 \times 1 \times 0.6 + (2 \times 2 \times 1^2) \times \omega$

On solving, we get

$\omega = \frac{1}{4}$ rad/s

Because the velocity of C.O.M is zero and the angular speed about the axis passing through C.O.M is 1/4 rad/s, the ring rotates in an anti-clockwise direction immediately after collision.

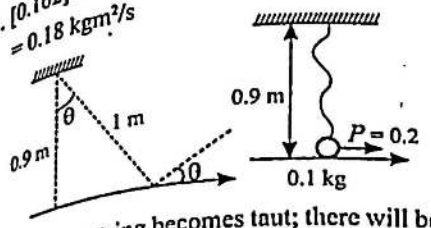
The velocity of the point of contact, i.e. the bottommost point of the ring, is in the right direction. As a result, friction will act on the ring in the left direction to counteract it.

As a result, both alternatives *A* and *C* are correct.

@FAKE_CBSE_X @RAJ_EDUCATION

52. [0.18] Angular momentum $L = P \times 0.9$
$= 0.18\ kgm^2/s$

53. [0.162] Angular momentum $L = P \times 0.9$
$= 0.18\ kgm^2/s$



Just after string becomes taut; there will be no velocity along the string.

$$\therefore V_\perp = \frac{P\cos\theta}{m} = \frac{0.2\times 0.9}{1\times 0.1} = 1.8\ m/s$$

$$\therefore K = \frac{1}{2}mv_\perp^2 = \frac{1}{2}\times 0.1\times 1.8^2 = 0.162\ J$$

54. [49] $L_S = L_{disc} + L_{rod}$

$$L_{disc} = \vec{r}\times M\vec{v}_{cm} + I_{cm}4\Omega,\ L_{rod} = \frac{Ma^2}{3}\Omega$$

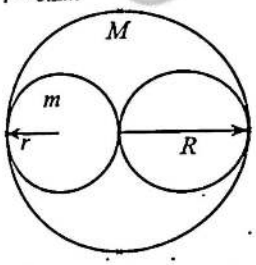
$$\Rightarrow L_s = \frac{3a}{4}\times\frac{3a}{4}\times M\Omega + \frac{Ma^2}{32}\times 4\Omega + \frac{Ma^2}{3}\Omega$$

$$= \frac{49}{48}Ma^2\Omega$$

55. [4] Using the principle of Angular momentum conservation,

$$L_1 = L_2$$
$$0 = I_2\omega_2 - I_1\omega_1$$
$$I_1\omega_1 = 2mvr$$
$$\left(\frac{0.4\times 0.5\times 0.5}{2}\right)$$
$$\omega_1 = 2\times 0.05\times 9\times 0.25$$
Hence, $\omega_1 = 4$

56. [8] Given,
The mass of the uniform disk is, $M = 50kg$
Radius of the disk, $R = 0.4m$
The disk is rotating with an angular velocity,
Two uniform circular rings, each of mass and radius $m = 6.25$ kg and radius $r = 0.2m$



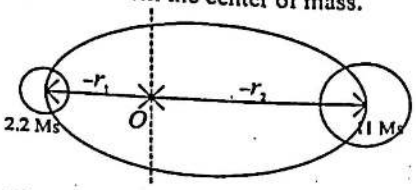
About vertical axis of disc the conservation of angular momentum

$$I_{Disc}\omega_1 = (I_{Disc} + 2I_{ring})\omega_2$$
$$\frac{50(0.4)^2}{2}\times 10$$
$$= \left[\frac{50(0.4)^2}{2} + 2\times 2(6.25)(0.2)^2\right]\omega$$

$\omega = 8$ rad/s

NOTE :
The moment of inertia for the rings will be $2mR^2$ each. Because the axis will be at the circumference

67. [6] Given $M_1 = 2.2M_s$ and $M_2 = 11M_s$.
Let R_1 and R_2 be their respective distances from the center of mass.



The total angular momentum about the center of mass is
$L_{Total} = (I_1 + I_2)\omega$
The angular momentum of B is
$L_2 = I_2\omega$

$$\frac{L_{Total}}{L_2} = \frac{I_1 + I_2}{I_2}$$
$$\frac{L_{Total}}{L_2} = 1 + \frac{I_2}{I_1}$$
$$\frac{L_{Total}}{L_2} = 1 + \frac{M_1R_1^2}{M_2R_2^2}$$
$$\frac{L_{Total}}{L_2} = 1 + \frac{M_1R_1^2}{M_2R_2^2}(as\ v = r\omega)$$
$$\frac{L_{Total}}{L_2} = 1 + \left(\frac{M_1R_1^2}{M_2R_2^2}\right)^2\times\frac{M_2}{M_1}$$
$$\frac{L_{Total}}{L_2} = 1 + \left(\frac{M_1v_1}{M_1v_1}\right)^2\times\frac{11}{2.2}$$
$$\{M_1v_1 = M_2v_2\}$$
$$\frac{L_{Total}}{L_2} = 6$$

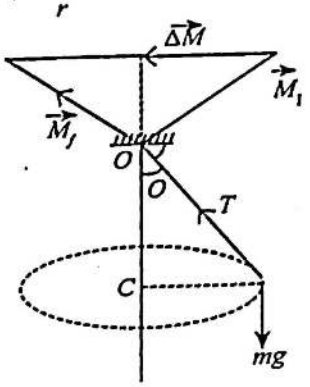
68. [3] The line of action of the force passes through the origin. Therefore, the torque about the origin will be zero and as a result, the angular momentum about the origin will remain conserved. Thus,

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{1}{\sqrt{2}} & \sqrt{2} & 0 \\ -\sqrt{2} & \sqrt{2} & \frac{2}{\pi} \end{vmatrix} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ x & y & 0.5 \\ v_x & v_y & \frac{2}{\pi} \end{vmatrix}$$

Equating coefficient of $\hat{k}$,
$[1 + 2] = [xv_y - yv_x]$
Thus, $xv_y - yv_x = 3$

69. Angular momentum is constant
We know that
$L = mvr$
Mass is also constant then,
$vr = c$ (constant)

$$v = \frac{C}{r}$$



Tension in the string is

$$T = \frac{mv^2}{r}$$

Given that
$T = Ar^n$

$$\frac{m}{r}\frac{c^2}{r^2} = Ar^n$$
$$Ar^n = mc^2r^{-3}$$

On comparing
$\therefore\ n = -3$

70. Take r be the perpendicular distance of CM from line AB and ω the angular velocity of the sheet just after colliding with rubber obstacle for the first time.
Linear velocity of CM before and after collision will be $v_i = (r)(1rad/s) = r$ and $v_f = r\omega$. v_i and v_f will be in opposite directions.
Also, linear impulse on CM
= change in linear momentum of CM

$$\text{or } 6 = m(v_f + v_i) = 30(r + r\omega) = \frac{1}{5}$$

So, angular impulse about AB = change in angular momentum about AB
Angular impulse = Linear impulse × perpendicular distance of impulse from AB
Therefore, $6(0.5\ m) = I_{AB}(\omega + 1)$
(Initial angular velocity = 1rad/s)
or $3 = [I_{CM} + Mr^2](1 + \omega)$
or $3 = [1.2 + 30r^2](1+\omega)$
Solving Eqs. (*i*) and (*ii*) for r, we get
$r = 0.4$ m and $r = 0.1$ m
But at $r = 0.4$ m comes out to be negative (−0.5rad/s) which is not acceptable.
Therefore,
(*a*) r = distance of CM from $AB = 0.1$ m

@FAKE_CBSE_@RAJEDUNET

(b) substituting $r = 0.1$ m in Eq. (i), we get 1rad/s i.e., the angular velocity with which sheet comes back after the first impact is 1rad/s.

(c) Since, the sheet returns with same angular velocity of 1rad/s, the sheet will never come to rest.

71. (c) Given that,

Radius of finger is r

Radius of ring is R

Angular velocity of the finger is ω_0

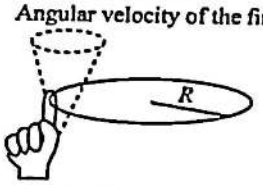


Figure 1

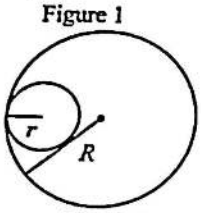


Figure 2

Here,

$\omega_0(R-r) = \omega R$

$\omega = \omega_0\left(\frac{R-r}{R}\right)$

Hence the total kinetic energy (Rotational + translational) is

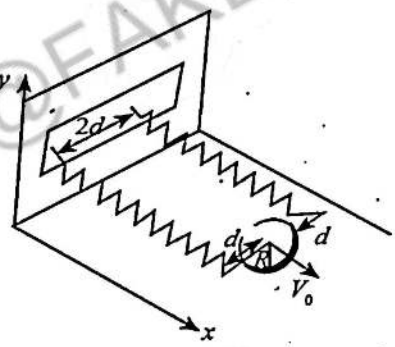
$$KE_{total} = \frac{1}{2}MR^2\omega_0 + \frac{1}{2}M\omega_0(R-r)^2$$

$$KE_{total} = \frac{1}{2}MR^2\omega_0 + M\omega_0R^2\left(1-\frac{r}{R}\right)^2$$

if $r << R; \frac{r}{R} \to 0$

$$KE_{total} = MR^2\omega_0$$

72. (c)



Mechanical energy will be conserved (pure rolling)

$$\frac{1}{2}Mv_0^2 + \frac{1}{2}\left(\frac{1}{2}MR^2\right)\left(\frac{0}{R}\right)^2 = 2\left(\frac{1}{2}\cdot KA^2\right)$$

$$\Rightarrow A = \sqrt{\frac{3M}{4K}}V_0$$

Now where A is the amplitude

$$\frac{2}{3}kA \le \mu Mg$$

Also $V_0 = A\omega \Rightarrow A = V_0\sqrt{\frac{3M}{4k}}$

$$\therefore \frac{2}{3}kV_0\sqrt{\frac{3M}{4k}} \le \mu Mg$$

$$\Rightarrow V_0 \le \mu g\sqrt{\frac{3M}{k}}$$

Hence, the maximum value of V_0

$$\mu g\sqrt{\frac{3M}{k}}$$

73. (c) $\frac{1}{2}I(2\omega)^2 = \frac{1}{2}kx_1^2 ; \frac{1}{2}(2I)(\omega)^2 = \frac{1}{2}kx_2^2$

Solving Eqs. (i) and (ii), we have

$$\frac{x_1}{x_2} = \sqrt{2}$$

74. (b) Taking W as angular velocity. Using conservation of angular momentum.

$(I+2I)w' = I(2w) + 2I(w)$

Loss of kinetic energy $= K_i - K_f$

$$= \left\{\frac{1}{2}I(2\omega)^2 + \frac{1}{2}(2I)(\omega)^2\right\} - \frac{1}{2}(3I)\left(\frac{4}{3}\omega\right)^2 = \frac{1}{3}I\omega^2$$

75. (b) Using angular momentum conservation

$I\omega_0 = I_1\omega_1$

Therefore, $I_1 = 2I$

$$\omega_1 = \frac{\omega_0}{2}$$

Initial kinetic energy

$$KE = \frac{I\omega_0^2}{2} = K$$

Final kinetic energy

$$KE = \frac{I_1\omega_1^2}{2} = \frac{2I\left(\frac{\omega_0}{2}\right)^2}{2} = \frac{K}{2}$$

76. (a, b) Given that,

Kinetic energies of ball A, B and C is K_A, K_B, and K respectively.

Height of ball A from the surface is h_A

Height of ball B from the surface is zero.

Height of ball C from the surface is h_C

Total energy of ball A

$E_A = mgh_A + K_A$

Total energy of ball B

$E_B = K_B$

Total energy of ball C

$E_C = mgh_C + K_C$

Using conservation of energy

$E_A = E_B = E_C$

$K_B > K_C, K_B > K_A$

or $K_B > K_C > K_A$

$h_A > h_C$

77. (a, c, d)

As $F_{ext} = 0$, so linear momentum of the system is conserved, Thus

$-2mv + m \times 2v + 0 = (2m + m + 8m)v_c$

or $v_c = 0$

Now as $\tau_{ext} = 0$, angular momentum of the system is also conserved, Thus

$m_1v_1r_1 + m_2v_2r_2 = (I_1 + I_2 + I_3)\omega$

or $2mva + m(2v)(2a)$

$$\left(2ma^2 + m(2a)^2 + \frac{8m\times(6a)^2}{12}\right)\omega$$

or $6mva = 30m\omega a^2$

or $\omega = \frac{v}{5a}$

Now as the system has no translatory motion but only rotatory motion we have

$$E = \frac{1}{2}I\omega^2 = \frac{1}{2}(30ma^2)\left(\frac{v}{2a}\right)^2 = \frac{3}{5}mv^2$$

78. [7] In case of disc

$$\frac{Trans.K.E.}{Rot.I.E.} = \frac{\frac{1}{2}mv^2}{\frac{1}{2}Iw^2} = \frac{2}{1}$$

$$K_{total} = K_{tr} + K_{rot} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$= \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{mR^2}{2}\right)\left(\frac{v}{R}\right)^2 = \frac{3}{4}mv^2$$

Since velocity of both the discs are same at B, using conservation of energy

$$\frac{3}{4}mv_1^2 + mg(30) = \frac{3}{4}mv_2^2 + mg(27)$$

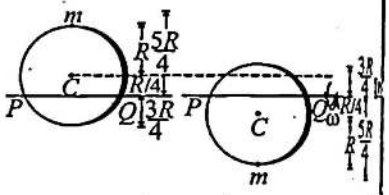
Putting $v_1 = 3$ and solving

$v_2^2 = 49 \quad v_2 = 7$

79. Initial and final positions are shown below

Decrease in potential energy of mass

$$= mg\left\{2\times\frac{5R}{4}\right\} = \frac{5mgR}{2}$$



Decrease in potential energy of disc

$$= mg\left\{2\times\frac{R}{4}\right\} = \frac{mgR}{2}$$

Therefore, total decrease in potential energy of system

@FAKE_CBSE_@RAJ_EDUNET

$= \frac{5mgR}{2} + \frac{mgR}{2} = 3mgR$

Gain in kinetic energy of system $= \frac{1}{2} I\omega^2$

where, I = moment of inertia of system (disc + mass) about axis PQ

= moment of inertia of disc + moment of inertia of mass

$I = \left\{\frac{mR^2}{4} + m\left(\frac{R}{4}\right)^2\right\} + m\left(\frac{5R}{4}\right)^2 ; I = \frac{15mR^2}{8}$

From conservation of mechanical energy,

Decrease in potential energy = Gain in kinetic energy

$\therefore 3mgR = \frac{1}{2}\left(\frac{15mR^2}{8}\right)\omega^2 \Rightarrow \omega = \sqrt{\frac{16g}{5R}}$

Therefore, linear speed of particle at its lowest point

$v = \left(\frac{5R}{4}\right)\omega = \frac{5R}{4}\sqrt{\frac{16g}{5R}} \quad v = \sqrt{5gR}$

80. (a) The cylinder rotates about the point of contact. Hence, the mechanical energy of the cylinder will be conserved i.e.

$\therefore (PE + KE)_1 = (PE + KE)_2$

$\therefore mgR + 0 = mgR\cos\theta + \frac{1}{2} I\omega^2 + \frac{1}{2} mv^2$

but $\omega = v/R$ (no slipping at point of contact) and

$I = \frac{1}{2} mR^2$

Therefore,

$mgR = mgR\cos\theta + \frac{1}{2}\left(\frac{1}{2} mR^2\right)\left(\frac{v^2}{R^2}\right) + \frac{1}{2} mv^2$

or $\frac{3}{4} v^2 = gR(1 - \cos\theta) N = 0$

or $\frac{v^2}{R} = \frac{4}{3} g(1 - \cos\theta)$

or $= \frac{4}{3} gR(1 - \cos\theta) \quad = m$

At the time of leaving contact, normal reaction $N = 0$ and $\theta = \theta_c$. hence,

$mg\cos\theta = \frac{mv^2}{R}$ or $\frac{v^2}{R} = g\cos\theta$

From Eqs. (*i*) and (*ii*),

$\frac{4}{3} g(1 - \cos\theta_c) = g\cos\theta_c$ or $\frac{7}{4}\cos\theta_c = 1$

or $\cos\theta_c = 4/7$ or $\theta_c = \cos^{-1}(4/7)$

(b) $v = \sqrt{\frac{4}{3} gR(1 - \cos\theta)}$

At the time of losing contact

$\cos\theta = \cos\theta_c = 4/7$

$\therefore v = \sqrt{\frac{4}{3} gR\left(1 - \frac{4}{7}\right)}$ or $v = \sqrt{\frac{4}{7} gR}$

Therefore, speed of CM of cylinder just before losing contact is $\sqrt{\frac{4}{7} gR}$

(c) At the moment, when cylinder loses contact

$v = \sqrt{\frac{4}{7} gR}$

Therefore, rotational kinetic energy,

$K_R = \frac{1}{2} I\omega^2$

or $K_R = \frac{1}{2}\left(\frac{1}{2} mR^2\right)\frac{v^2}{R^2} = \frac{1}{4} mv^2$

$= \frac{1}{4} m\left(\frac{4}{7} gR\right)$

or $\kappa_R = \frac{mgR}{7}$

Now, once the cylinder loses its contact, $N = 0$, i.e the frictional force, which is responsible for its rotation, also vanishes. Hence, its rotational kinetic energy now becomes constant, while its translational kinetic energy increases. Applying conservation of energy at (*a*) and (*c*).

Decrease in gravitational PE

= Gain in rotational KE + translational KE

$\therefore$ Translational $KE(K_T)$

= Decrease in gravitational $PE - K_R$

or $K_T = (mgR) - \frac{mgR}{7} = \frac{6}{7} mgR$

$\therefore \frac{K_T}{K_R} = \frac{\frac{6}{7} mgR}{\frac{mgR}{7}}$ or $\frac{K_T}{K_R} = 6$

81. System is free to rotate but not free to translate. During collision, net torque on the system (rod A + rod B + mass m) about point P is zero.

= Angular momentum of system just after collision. (About P) Let ω be the angular velocity of system just after collision, then

$L_i = L_f$

$\Rightarrow mv(2l) = I\omega$ ...(*i*)

Here, I = moment of inertia of system about P

$= m(2l)^2 + m_A\left(l^2/3\right) + m_B\left[\frac{l^2}{12} + \left(\frac{1}{2} + 1\right)^2\right]$

Given: $l = 0.6$ m, $m = 0.05$, $m = 0.05$ kg, $m_A = 0.01$ kg and mB = 0.02 kg

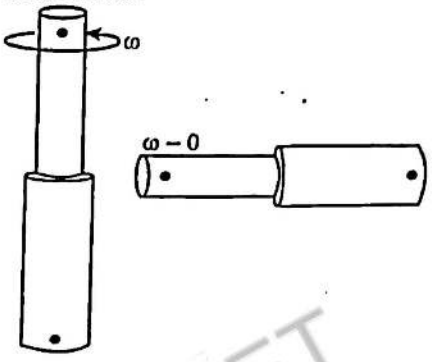
Substituting the values, we get

$I = 0.09$ kg-m^2

$\omega = \frac{2mvl}{I} = \frac{(2)(0.05)(v)(0.6)}{0.09}$

$\omega = 0.67v$ ...(*ii*)

Now, after collision, mechanical energy will be conserved.



Therefore, decrease in rotational KE = increase in gravitational PE

or $\frac{1}{2} I\omega^2 = mg(2l) + m_A g\left(\frac{l}{2}\right) + m_B g\left(l + \frac{l}{2}\right)$

or $\omega^2 = \frac{gl(4m + m_A + 3m_B)}{I}$

$= \frac{(9.8)(0.6)(4 \times 0.05 + 0.01 + 3 \times 0.02)}{0.09}$

$= 17.64$ (rad/s)2

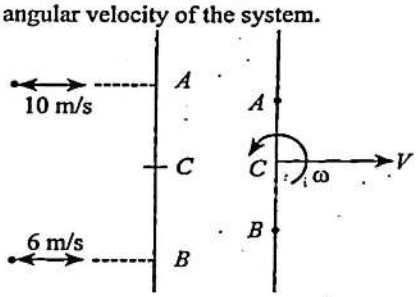
$\therefore \omega = 4.2$ rad/s ...(*iii*)

Equating Eqs. (*ii*) and (*iii*), we get

$V = \frac{4.2}{0.67}$ m/s

or $v = 6.3$ m/s

82. Let v be the velocity of centre of mass (also at c) of rod and two particles and ω the angular velocity of the system.



From conservation of linear momentum

$(0.08)(10)(0.5) - (0.08)(6)(0.5) = I\omega$ ...(*i*)

Here, $I = I_{rod} + I_{two\ particles}$

$= \frac{(1.6)\left(\sqrt{3}\right)^2}{12} + 2(0.08)(.05)^2 = 0.08$ kg-m^2

Substituting in equation (*i*), we get

$\omega = 2$ rad/s

Loss of kinetic energy

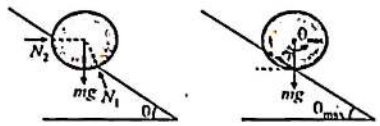
@FAKE_CBSE_KOTA_EDUKET

$$=\frac{1}{2}(0.08)(10)^2+\frac{1}{2}(0.08)(2)^2$$

$$-\frac{1}{2}(0.08+0.08+0.16)(4)^2-\frac{1}{2}(0.08)(2)^2$$

$$=4+1.44+-2.56-0.16=2.72\text{J}$$

83. (*a*)



For θ_{max}, the football is about to roll, then $N_2 = 0$ and all forces (Mg and N_1) must pass through contact point

$$\therefore \cos(90°-\theta_{max})=\frac{r}{R}\Rightarrow \sin\theta_{max}=\frac{r}{R}$$

84. (*b*) For no slipping at the ground, the center of roller moves with speed

$V_{centre}=\omega R$ (R is radius of roller)

$\therefore$ Velocity of scale $=(V_{center}+\omega r)$

[r is radius of axle]

It is given that $V_{center}\cdot t = 50$ cm

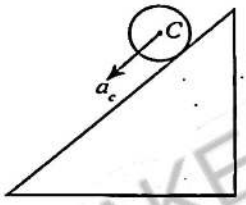
$\therefore$ Distance moved by scale

$$=(V_{center}+\omega r)t$$

$$=\left(V_{center}+\frac{V_{center}r}{R}\right)t=\frac{3V_{center}}{2}\cdot t=75\text{ cm}$$

$$\left(r=\frac{R}{2}\right)$$

85. (*d*) The acceleration of the centre of mass of cylinder rolling down an inclined plane is



$$a_c=\frac{Mg\sin\theta}{\left(M+\frac{I}{R^2}\right)}$$

$$a_P=\frac{Mg\sin\theta}{\left(M+\frac{MR^2}{R^2}\right)}=\frac{g}{2}$$

$a_Q = g\sin\theta$ as i_Q is similar to 0.

$$\omega_P=\frac{\sqrt{2\times\frac{gl}{2}}}{R}$$

$$\omega_Q=\sqrt{\frac{2gl}{R}}$$

Thus, $\omega_P > \omega_Q$

Hence Cylinder Q reaches the ground with larger angular speed.

86. (*d*) The acceleration of an object down an incline of angle 0 is

$$a=\frac{g\sin g0}{1+\frac{I}{mR^2}}$$

Now, $I_{hollow} > I_{solid}$ for same mass and dimensions

And $a_{hollow} < a_{solid}$

Solid Cylinders will reach the bottom first, which means Statement-I is false.

87. (*d*) There are no non-conservative forces acting on the body

Hence,

Using Law of conservation of energy

$$\frac{1}{2}mv^2+\frac{1}{2}I\omega^2=mg\left(\frac{3v^2}{4g}\right) \quad ...(i)$$

For pure rolling condition,

$$\omega=\frac{v}{R}$$

Putting the value of in equation (*i*).

$$\frac{1}{2}mv^2+\frac{1}{2}I\left(\frac{v^2}{R}\right)=mg\left(\frac{3v^2}{4g}\right)$$

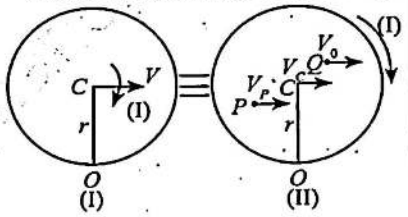
$$\frac{1}{2}I\left(\frac{v^2}{R}\right)=m\left(\frac{3v^2}{4}\right)-\frac{1}{2}mv^2$$

$$\frac{1}{2}I\left(\frac{v^2}{R}\right)=\frac{1}{4}mv^2$$

$$I=\frac{1}{2}mR^2$$

Hence the object is a disc.

88. (*a*) For the case of pure rolling the points where velocity is zero are at the bottom.



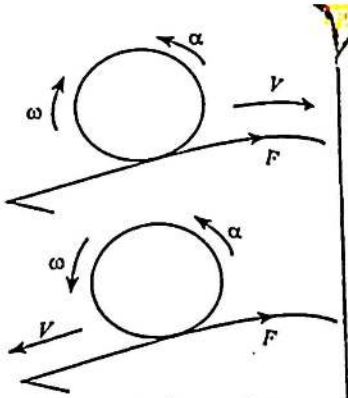
Velocity of any arbitrary point on the disc, $v = r\omega$

where r is the distance of point from 0

$r_Q > r_C > r_P$

Hence, $v_Q > v_C > v_P$

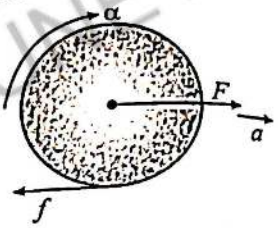
89. (*b*) Angular velocity ω of the cylinder decreases in the clockwise direction when the cylinder rolls up the incline. This requires an anticlockwise angular acceleration α, which is provided by the force of friction (F) acting up the incline.



Angular velocity ω of the cylinder increases in an anticlockwise direction when the cylinder rolls down the incline.

This requires an anticlockwise angular acceleration α, which is provided by the force of friction (F) acting up the incline.

90. (*b, d*)



$$F-f=ma_C \quad fR=I_C\alpha$$

$$a_C-\alpha R=0$$

$$F-I_C\frac{\alpha}{R}=ma_C\Rightarrow a_C=\frac{F}{\frac{I_C}{R^2}+m}$$

So, (*a*) is incorrect

$$f=\frac{I_C\alpha}{R}=\frac{I_C}{R^2}a_C=\frac{I_C}{R^2}\frac{F}{\left[\frac{I_C}{R^2}+m\right]}$$

$$=\frac{F}{\left[1+\frac{mR^2}{I_C}\right]}$$

Thin walled hollow cylinder

$$I_C=mR^2\Rightarrow a_C=\frac{F}{2m}$$

So, (*d*) is correct

Now, $fR=I_C\alpha=\frac{I_Ca_C}{R}$

$$\Rightarrow f=\frac{I_Ca_C}{R^2}\le\mu mg$$

$$\Rightarrow a_C\le\frac{\mu mgR^2}{I_C}=\mu g$$

For solid cylinder $I_C=\frac{mR^2}{2}$

@FAKE_CBSE_K @RAJ_EDUNET

$a_c \le 2\mu g$

$(a_c)_{max} = 2\mu g$

So, (b) is correct.

91. (c,d) The frictional for u opposes the linear motion of the body, therefore it reduces the linear velocity of the body some frictional force will be applied which is always less than $\mu mg\cos\theta$ because the sphere is not sliding, and no energy dissipation * The frictional force supports the rotational motion of the sphere and hence it increases its angular velocity.

92. [2.86] Translation motion of COM:

$+1-1-f=1a$

$-f=a$ ...(i)

rotational motion about COM:

$f1-2(1(0.5)) = \frac{2}{5}Mr^2\alpha$

$\Rightarrow f-1 = \frac{2}{5}a \Rightarrow f = 1+\frac{2}{5}a$ ...(ii)

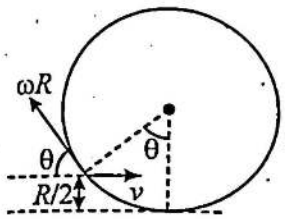
From equations (i) and (ii),

$5-a = 1+\frac{2}{5}a$

$\Rightarrow 4 = \frac{7a}{5} \Rightarrow a = \frac{20}{7} = 2.86\ m/s^2$

93. [0.52]

$\theta = \frac{1}{2}\alpha t^2 \Rightarrow \theta = \frac{1}{2}\times\frac{2}{3}\times\pi = \frac{\pi}{3} = 60°$



At $t=0, \omega=0$

at $t=\sqrt{\pi}, \omega=\alpha t=\frac{2}{3}\sqrt{\pi}$

$\Rightarrow v=\omega r=\frac{2}{3}\sqrt{\pi}$

Now, $v_y = v\sin 60 = \frac{\sqrt{3}}{2}v$

So, $h = \frac{v_y^2}{2g} = \frac{\frac{3}{4}v^2}{2g} = \frac{\frac{3}{4}\times\frac{4}{9}\pi}{2g}$

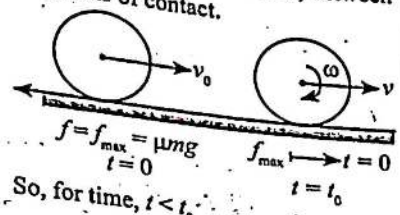
$= \frac{3\pi}{9\times 2g} = \frac{\pi}{6g}$

Maximum height from plane, $H = \frac{R}{2}+h$

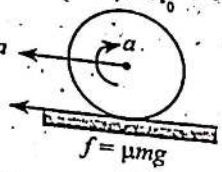
$H = \frac{1}{2}+\frac{\pi}{6\times 10}$

$\Rightarrow x = \frac{\pi}{6}; x = 0.52$

94. (a) Between the time $t=0$ to $t=t_0$. There is forward sliding, so friction f is leftwards and maximum i.e. μmg. For time $t > t_0$, friction f will become zero, because now pure rolling has started i.e. there is no sliding (no relative motion) between the points of contact.



So, for time, $t < t_0$



Linear retardation, $a = \frac{f}{m} = \mu g$

and angular acceleration,

$\alpha = \frac{\tau}{I} = \frac{fR}{\frac{1}{2}mR^2} = \frac{2\mu g}{R}$

Now, let v be the linear velocity and ω, the angular velocity of the disc at time $t=t_0$, then

$v = v_0 - at_0 = v_0 - \mu g t_0$

and $\omega = \alpha t_0 = \frac{2\mu g t_0}{R}$

For pure rolling to take place

$v = R\omega$

i.e. $v_0 - \mu g t_0 = 2\mu g t_0 \Rightarrow t_0 = \frac{v_0}{3\mu g}$

Substituting in Eq. (i), we have

$v = v_0 - \mu g\left(\frac{v_0}{3\mu g}\right) \Rightarrow v = \frac{2}{3}v_0$

(b) Work done by friction

For $t \le t_0$, linear velocity of disc at any time t is $v = v_0 - \mu g t$ and angular velocity is $\omega - \alpha t - \frac{2\mu g t}{R}$.

From Work-energy theorem, work done by friction upto time t = Kinetic energy of the disc at time t – Kinetic energy of the disc at time $t=0$

$\therefore W = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 - \frac{1}{2}mv_0^2$

$= \frac{1}{2}m\left[v_0 - \mu g t\right]^2 + \frac{1}{2}\left(\frac{1}{2}mR^2\right)\left(\frac{2\mu g t}{R}\right)^2 - \frac{1}{2}mv_0^2$

$= \frac{1}{2}\left[mv_0^2 + m\mu^2 g^2 t^2 - 2mv_0\mu g t + 2m\mu^2 g^2 t^2 - mv_0^2\right]$

or $W = \frac{m\mu g t}{2}\left[3\mu g t - 2v_0\right]$

For $t > t_0$, friction force is zero i.e. work done in friction is zero. Hence, the energy will be conserved.

Therefore, total work done by friction over a time t much longer then t_0 is total work done upto time t_0 (because beyond this work done by friction is zero) which is equal to

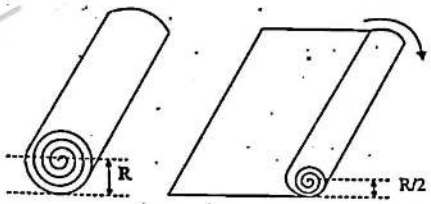
$W = \frac{m\mu g t_0}{2}\left[3\mu g t_0 - 2v_0\right]$

Substituting $t_0 = v_0/3\mu g$, we get

$W = \frac{mv_0}{6}\left[v_0 - 2v_0\right] \Rightarrow W = -\frac{mv_0^2}{6}$

95. Rolling motion is due to lowering of centre of mass in unrolling.

Potential Energy is converted to kinetic energy of the rolling part.



Initial potential energy = MgR

Mass of carpet of radius

$\frac{R}{2}$ is $\frac{M}{4}$

Hence Potential energy is

$= \frac{MgR}{8}$

By using energy conservation:

$\frac{1}{2}\left(Mv^2\right) + \frac{1}{2}\left(I\omega^2\right) = MgR - \frac{MgR}{8}$

By putting value of I and v

$\frac{3}{16}Mv^2 = \frac{7}{8}MgR$

$v = \sqrt{\frac{14gR}{3}}$

Hence, The horizontal velocity

$v = \sqrt{\frac{14gR}{3}}$

@FAKE_CBSE_X@RAJ_EDUNET

9 Gravitation

Scan for Sol.

JEE-Main

Newton's Law of Gravitation & Field

1. Four identical particles of mass m are kept at the four corners of a square. If the gravitational force exerted on one of the masses by the other masses is $\left(\frac{2\sqrt{2}+1}{32}\right)\frac{Gm^2}{L^2}$, the length of the sides of the square is **[31 Jan, 2024 (Shift-I)]**

(a) $\frac{L}{2}$ (b) 4L (c) 3L (d) 2L

2. A metal wire of uniform mass density having length L and mass M is bent to form a semicircular arc and a particle of mass m is placed at the centre of the arc. The gravitational force on the particle by the wire is: **[04 April, 2024 (Shift-I)]**

(a) $\frac{GMm\pi}{2L^2}$ (b) 0 (c) $\frac{GmM\pi^2}{L^2}$ (d) $\frac{2GmM\pi}{L^2}$

3. Two identical particles each of mass 'm' go round a circle of radius a under the action of their mutual gravitational attraction. The angular speed of each particle will be: **[15 April, 2023 (Shift-I)]**

(a) $\sqrt{\frac{Gm}{2a^3}}$ (b) $\sqrt{\frac{Gm}{8a^3}}$ (c) $\sqrt{\frac{Gm}{4a^3}}$ (d) $\sqrt{\frac{Gm}{a^3}}$

4. Two particles of equal masses 'm' move in a circle of radius 'r' under the action of their mutual gravitational attraction. The speed of each particle will be: **[29 Jan, 2023 (Shift-I)]**

(a) $\sqrt{\frac{Gm}{2r}}$ (b) $\sqrt{\frac{4Gm}{r}}$ (c) $\sqrt{\frac{Gm}{r}}$ (d) $\sqrt{\frac{Gm}{4r}}$

5. Two objects of equal masses placed at certain from each other attracts each other with a force of F. If one-third mass of one object is transferred to the other, then the new force will be: **[28 June, 2022 (Shift-II)]**

(a) 2/9 F (b) 16/9 F (c) 8/9 F (d) F

6. Three identical particles A, B and C of mass 100 kg each are placed in a straight line with $AB = BC = 13$m. The gravitational force on a fourth particle P of the same mass is F, when placed at a distance 13 m from the particle B on the perpendicular bisector of the line AC. The value of F will be approximately: **[25 July, 2022 (Shift-I)]**

(a) 21 G (b) 100 G (c) 59 G (d) 42 G

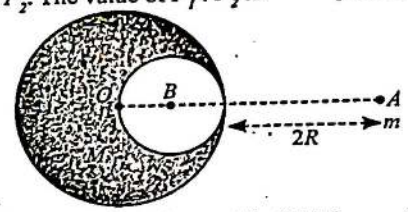
7. Given below are two statements.
Statement-I: The law of gravitation holds good for any pair of bodies in the universe.
Statement-II: The weight of any person becomes zero when the person is at the centre of the earth.
In the light of the above statements, choose the correct answer from the option given below. **[27 June, 2022 (Shift-I)]**
(a) Both Statement-I and Statement-II are true
(b) Both Statement-I and Statement-II are false
(c) Statement-I is true but Statement-II is false
(d) Statement-I is false but Statement-II is true

8. Four identical particles of equal masses 1 kg made to move along the circumference of a circle of radius 1 m under the action of their own mutual gravitational attraction. The speed of each particle will be: **[24 Feb, 2021 (Shift-I)]**

(a) $\frac{\sqrt{(1+2\sqrt{2})G}}{2}$ (b) $\sqrt{\frac{G}{2}(1+2\sqrt{2})}$

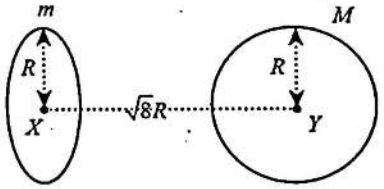
(c) $\sqrt{\frac{G}{2}(2\sqrt{2}-1)}$ (d) $\frac{1}{2}\sqrt{G(1+2\sqrt{2})}$

9. A solid sphere of radius R gravitationally attracts a particle placed at $3R$ from its centre with a force F. Now a spherical cavity of radius $\left(\frac{R}{2}\right)$ is made in the sphere (as shown in figure) and the force becomes F_2. The value of $F_1 : F_2$ is: **[25 Feb, 2021 (Shift-I)]**



(a) 36:25 (b) 50:41 (c) 25:36 (d) 41:50

10. Find the gravitational force of attraction between the ring and sphere as shown in the diagram, where the plane of the ring is perpendicular to the line joining the centres. If $\sqrt{8}R$ is the distance between the centres of a ring (of mass 'm') and a sphere (mass 'M') where both have equal radius 'R'. **[26 Feb, 2021 (Shift-I)]**

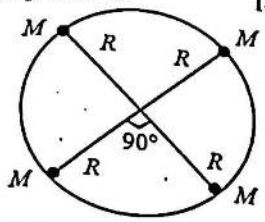


(a) $\frac{\sqrt{8}}{9}\cdot\frac{GmM}{R}$ (b) $\frac{1}{3\sqrt{8}}\cdot\frac{GMm}{R^2}$

(c) $\frac{\sqrt{8}}{27}\cdot\frac{GmM}{R^2}$ (d) $\frac{2\sqrt{2}}{3}\cdot\frac{GMm}{R^2}$

PEAK_OBSTACLE@REDUMIT

11. Four particles each of mass M, move along a circle of radius R under the action of their mutual gravitational attraction as shown in figure. The speed of each particle is: **[1 Sept, 2021 (Shift-II)]**



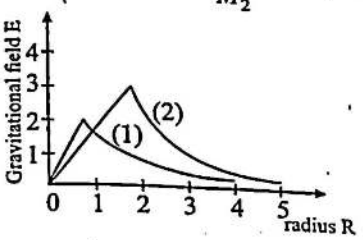
(a) $\frac{1}{2}\sqrt{\frac{GM}{R(2\sqrt{2}+1)}}$ (b) $\frac{1}{2}\sqrt{\frac{GM}{R}(2\sqrt{2}-1)}$

(c) $\frac{1}{2}\sqrt{\frac{GM}{R}(2\sqrt{2}+1)}$ (d) $\sqrt{\frac{GM}{R}}$

12. The mass density of a planet of radius R varies with the distance r from its centre as $\rho(r)=\rho_0\left(1-\frac{r^2}{R^2}\right)$. Then the gravitational field is maximum at **[3 Sep, 2020 (Shift-II)]**

(a) $r=R\frac{1}{\sqrt{3}}$ (b) $r=\sqrt{\frac{3}{4}}R$ (c) $r=\sqrt{\frac{5}{9}}R$ (d) $r=R$

13. Consider two solid spheres of radii $R_1 = 1\text{m}$, $R_2 = 2\text{m}$ and masses M_1 and M_2, respectively. The gravitational field due to sphere (1) and (2) are shown. The value of $\frac{M_1}{M_2}$ is **[8 Jan, 2020 (Shift-I)]**



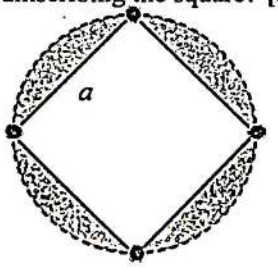
(a) $\frac{2}{3}$ (b) $\frac{1}{3}$ (c) $\frac{1}{2}$ (d) $\frac{1}{6}$

14. A straight rod of length L extends from $x = a$ to $x = L + a$. The gravitational force it exerts on a point mass 'm' at $x = 0$, if the mass per unit length of the rod is $A + Bx^2$, is given by **[12 Jan, 2019 (Shift-I)]**

(a) $Gm\left[A\left(\frac{1}{a+L}-\frac{1}{a}\right)-BL\right]$ (b) $Gm\left[A\left(\frac{1}{a}-\frac{1}{a+L}\right)-BL\right]$

(c) $Gm\left[A\left(\frac{1}{a+L}-\frac{1}{a}\right)+BL\right]$ (d) $Gm\left[A\left(\frac{1}{a}-\frac{1}{a+L}\right)+BL\right]$

15. Four identical particles of mass M are located at the corners of a square of side 'a'. What should be their speed if each of them revolves under the influence of other's gravitational field in a circular orbit circumscribing the square? **[8 April, 2019 (Shift-I)]**



(a) $1.21\sqrt{\frac{GM}{a}}$ (b) $1.41\sqrt{\frac{GM}{a}}$ (c) $1.16\sqrt{\frac{GM}{a}}$ (d) $1.35\sqrt{\frac{GM}{a}}$

16. A solid sphere of mass 'M' and radius 'a' is surrounded by a uniform concentric spherical shell of thickness $2a$ and mass $2M$. The gravitational field at distance '$3a$' from the centre will be: **[9 April, 2019 (Shift-I)]**

(a) $\frac{2GM}{9a^2}$ (b) $\frac{GM}{3a^2}$ (c) $\frac{GM}{9a^2}$ (d) $\frac{2GM}{3a^2}$

17. Consider a spherical gaseous cloud of mass density $\rho(r)$ in free space where r is the radial distance from its center. The gaseous cloud is made of particles of equal mass m moving in circular orbits about the common center with the same kinetic energy K. The force acting on the particles is their mutual gravitational force.
If $\rho(r)$ is constant in time, the particle number density $n(r) = \rho(r)/m$ is
[G is universal gravitational constant] **[JEE Adv, 2019]**

(a) $\frac{K}{6\pi r^2m^2G}$ (b) $\frac{K}{\pi r^2m^2G}$ (c) $\frac{3K}{\pi r^2m^2G}$ (d) $\frac{K}{2\pi r^2m^2G}$

18. A test particle is moving in a circular orbit in the gravitational field produced by a mass density $\rho(r)=\frac{K}{r^2}$. Identify the correct relation between the radius R of the particle's orbit and its period T **[9 April, 2019 (Shift-II)]**

(a) T/R^2 is a constant (b) TR is a constant
(c) T^2/R^3 is a constant (d) T/R is a constant

Acceleration Due to Gravity, Weight

19. At what distance above and below the surface of the earth a body will have same weight, (take radius of earth as R.) **[29 Jan, 2024 (Shift-I)]**

(a) $\sqrt{5}R-R$ (b) $\frac{\sqrt{3}R-R}{2}$ (c) $\frac{R}{2}$ (d) $\frac{\sqrt{5}R-R}{2}$

20. The acceleration due to gravity on the surface of earth is g. If the diameter of earth reduces to half of its original value and mass remains constant, then acceleration due to gravity on the surface of earth would be: **[27 Jan, 2024 (Shift-I)]**

(a) $\frac{g}{4}$ (b) 2g (c) $\frac{g}{2}$ (d) 4g

21. A simple pendulum is placed at a place where its distance from the earth's surface is equal to the radius of the earth. If the length of the string is 4 m, then the time period of small oscillations will be _____s. [take $g = \pi^2\ \text{ms}^{-2}$] **[30 Jan, 2024 (Shift-II)]**

22. If R is the radius of the earth and the acceleration due to gravity on the surface of earth is $g = \pi^2\ \text{m/s}^2$, then the length of the second's pendulum at a height $h = 2R$ from the surface of earth will be,: **[1 Feb, 2024 (Shift-I)]**

(a) $\frac{2}{9}$m (b) $\frac{1}{9}$ (c) $\frac{4}{9}$ (d) $\frac{8}{9}$

23. Assuming the earth to be a sphere of uniform mass density, a body weighed 300 N on the surface of earth. How much it would weigh at $R/4$ depth under surface of earth? **[06 April, 2024 (Shift-II)]**

(a) 75 N (b) 375 N (c) 300 N (d) 225 N

24. A 90 kg body placed at 2R distance from surface of earth experiences gravitational pull of :
(R = Radius of earth, $g = 10\ \text{ms}^{-2}$) **[04 April, 2024 (Shift-II)]**

(a) 300 N (b) 225 N (c) 120 N (d) 100 N

@TAKE OFF X @RAI EDUCATE

25. Assuming the earth to be a sphere of uniform mass density, the weight of a body at a depth $d = \frac{R}{2}$ from the surface of earth, if its weight on the surface of earth is 200 N, will be:
(Given R = Radius of earth) **[10 April, 2023 (Shift-I)]**
(a) 400 N (b) 500 N (c) 300 N (d) 100 N

26. Given below are two statements:
Statement-I: Acceleration due to gravity is different at different places on the surface of earth.
Statement-II: Acceleration due to gravity increases as we go down below the earth's surface.
In the light of the above statements, choose the correct answer from the options given below **[01 Feb, 2023 (Shift-I)]**
(a) Both Statement-I and Statement-II are true
(b) Both Statement-I and Statement-II are false
(c) Statement-I is true but Statement-II is false
(d) Statement-I is false but Statement-II is true

27. The radii of two planets 'A' and 'B' are 'R' and '$4R$' and their densities are ρ and $\rho/3$ respectively. The ratio of acceleration due to gravity at their surfaces ($gA : gB$) will be:
[11 April, 2023 (Shift-I)]
(a) 1 : 16 (b) 3 : 16 (c) 3 : 4 (d) 4 : 3

28. The weight of a body at the surface of earth is 18 N. The weight of the body at an altitude of 3200 km above the earth's surface is (given, radius of earth $Re = 6400$ km) **[24 Jan, 2023 (Shift-I)]**
(a) 9.8 N (b) 4.9 N (c) 19.6 N (d) 8 N

29. T is the time period of a simple pendulum on the earth's surface. Its time period becomes xT when taken to a height R (equal to earth's radius) above the surface of earth. Then, the value of x will be:
[25 Jan, 2023 (Shift-I)]
(a) 4 (b) 2 (c) $\frac{1}{2}$ (d) $\frac{1}{4}$

30. The weight of a body on the earth is 400 N. Then weight of the body when taken to a depth half of the radius of the earth will be:
[08 April, 2023 (Shift-I)]
(a) Zero (b) 300 N (c) 100 N (d) 200 N

31. Given below are two statements:
Statement-I: Rotation of the earth shows effect on the value of acceleration due to gravity (g).
Statement-II: The effect of rotation of the earth on the value of 'g' at the equator is minimum and that at the pole is maximum.
In the light of the above statements, choose the correct answer from the options given below. **[10 April, 2023 (Shift-II)]**
(a) Statement-I is false but Statement-II is true.
(b) Statement-I is true but Statement-II are false.
(c) Both Statement-I and Statement-II are true.
(d) Both Statement-I and Statement-II are false.

32. Given below are two statements:
Statement-I: Acceleration due to earth's gravity decreases as you go 'up' or 'down' from earth's surface.
Statement-II: Acceleration due to earth's gravity is same at a height 'h' and depth 'd' from earth's surface, if $h = d$.
In the light of above statements, choose the most appropriate answer form the options given below **[24 Jan, 2023 (Shift-II)]**
(a) Statement-I is incorrect but Statement-II is correct
(b) Both Statement-I and Statement-II are incorrect
(c) Statement-I is correct but Statement-II is incorrect
(d) Both Statement-I and II are correct

33. A body weight W, is projected vertically upwards from earth's surface to reach a height aboZve the earth which is equal to nine times the radius of earth. The weight of the body at that height will be: **[31 Jan, 2023 (Shift-II)]**
(a) $\frac{W}{91}$ (b) $\frac{W}{100}$ (c) $\frac{W}{9}$ (d) $\frac{W}{3}$

34. A planet has double the mass of the earth. Its average density is equal to the that of the earth. An object weighing W on earth will weight on that planet: **[06 April, 2023 (Shift-I)]**
(a) $2^{1/3}W$ (b) W (c) $2^{1/3}W$ (d) $2W$

35. The acceleration due to gravity at height h above the earth if $h <<$ R (radius of earth) is given by **[08 April, 2023 (Shift-II)]**
(a) $g' = g\left(1-\frac{2h}{R}\right)$ (b) $g' = g\left(1-\frac{2h^2}{R^2}\right)$
(c) $g' = g\left(1-\frac{h}{2R}\right)$ (d) $g' = g\left(1-\frac{h^2}{2R^2}\right)$

36. Two planets A and B of radii R and 1.5 R have densities ρ and $\rho/2$ respectively. The ratio of acceleration due to gravity at the surface of B to A is: **[13 April, 2023 (Shift-II)]**
(a) 2 : 3 (b) 2 : 1 (c) 3 : 4 (d) 4 : 3

37. At a certain depth "d" below surface of earth, value of acceleration due to gravity becomes four times that of its value at a height $3R$ above earth surface. Where R is Radius of earth (Take $R = 6400$ km). The depth d is equal to **[31 Jan, 2023 (Shift-I)]**
(a) 5260 km (b) 640 km (c) 2560 km (d) 4800 km

38. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.
Assertion (A): A pendulum clock when taken to Mount Everest becomes fast.
Reason (R): The value of g (acceleration due to gravity) is less at Mount Everest than its value on the surface of earth.
In the light of the above statements, choose the most appropriate answer from the options given below **[24 Jan, 2023 (Shift-II)]**
(a) Both A and R are correct but R is NOT the correct explanation of A
(b) Both A and R are correct and R is the correct explanation of A
(c) A is not correct but R is correct
(d) A is correct but R is not correct

39. The weight of a body on the surface of the earth is 100 N. The gravitational force on it when taken at a height, from the surface of earth, equal to one fourth the radius of the earth is:
[06 April, 2023 (Shift-II)]
(a) 100 N (b) 64 N (c) 50 N (d) 25 N

40. The height of any point P above the surface of earth is equal to diameter of earth. The value of acceleration due to gravity at point P will be: (Given g = acceleration due to gravity at the surface of earth). **[25 June, 2022 (Shift-I)]**
(a) $\frac{g}{2}$ (b) $\frac{g}{4}$ (c) $\frac{g}{3}$ (d) $\frac{g}{9}$

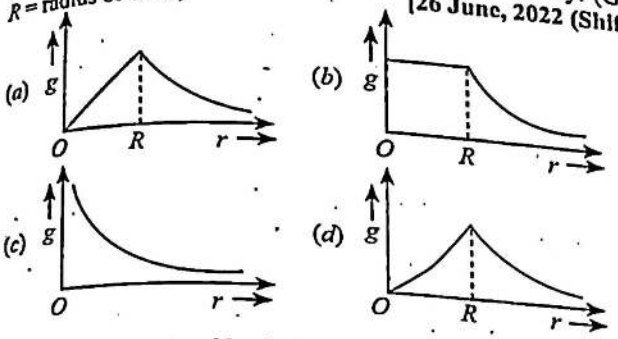
41. Given below are two statements: One is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A): If we move from poles to equator, the direction of acceleration due to gravity of earth always points towards the centre of earth without any variation in its magnitude.
Reason (R): At equator, the direction of acceleration due to the gravity is towards the centre of earth.
In the light of above statements, choose the correct answer from the options given below **[26 June, 2022 (Shift-II)]**

CBSE_CBSE X @ REDMI

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is NOT the correct explanation of A.
(c) A is true but R is false
(d) A is false but R is true

42. If the radius of earth shrinks by 2% while its mass remains same. The acceleration due to gravity on the earth's surface will approximately: **[28 July, 2022 (Shift-I)]**
(a) Decrease by 2% (b) Decrease by 4%
(c) Increase by 2% (d) Increase by 4%

43. The variation of acceleration due to gravity (g) with distance (r) from the centre of the earth is correctly represented by: (Given R = radius of earth) **[26 June, 2022 (Shift-I)]**



44. Assume there are two identical simple pendulum clocks. Clock – 1 is placed on the earth and Clock – 2 is placed on a space station located at a height h above the earth surface. Clock – 1 and Clock – 2 operate at time periods 4 s and 6 s respectively. Then the value of h is – (consider radius of earth R_E = 6400km and g on earth 10 m/s²) **[28 July, 2022 (Shift-II)]**
(a) 1200 km (b) 1600 km (c) 3200 km (d) 4800 km

45. The approximate height from the surface of earth at which the weight of the body becomes 1/3 of its weight on the surface of earth is: **[24 June, 2022 (Shift-I)]**
[Radius of earth R = 6400 km and $\sqrt{3}$ = 1.732]
(a) 3840 km (b) 4685 km
(c) 2133 km (d) 4267 km

46. The length of a seconds pendulum at a height $h = 2R$ from earth surface will be: **[25 July, 2022 (Shift-II)]**
(Given R = Radius of earth and acceleration due to gravity at the surface of earth, $g = \pi^2 ms^{-2}$)
(a) $\frac{2}{9}$m (b) $\frac{4}{9}$m
(c) $\frac{8}{9}$m (d) $\frac{1}{9}$m

47. An object is taken to a height above the surface of earth at a distance 5/4 R from the centre of the earth. Where radius of earth, R = 6400 km. The percentage decrease in the weight of the object will be: **[25 July, 2022 (Shift-II)]**
(a) 36% (b) 50%
(c) 64% (d) 25%

48. The percentage decrease in the weight of a rocket, when taken to a height of 32 km above the surface of earth will, be:
(Radius of earth = 6400 km) **[26 July, 2022 (Shift-I)]**
(a) 1% (b) 3%
(c) 4% (d) 0.5%

49. If the acceleration due to gravity experienced by a point mass at a height h above the surface of earth is same as that of the acceleration due to gravity at a depth αh ($h << R_e$) from the earth surface. The value of α will be _____.
(use R_e = 6400 km) **[29 July, 2022 (Shift-I)]**

50. If the angular velocity of earth's spin is increased such that the bodies at the equator start floating, the duration of the day would be approximately:
[Take g = 10 ms⁻², the radius of earth, $R = 6400 \times 10^3$ m, Take π = 3.14] **[18 March, 2021 (Shift-II)]**
(a) 1200 minutes (b) Does not change
(c) 60 minutes (d) 84 minutes

51. If R_E be the radius of Earth, then the ratio between the acceleration due to gravity at a depth 'r' below and a height 'r' above the earth surface is: **[31 Aug, 2021 (Shift-II)]**
(a) $1+\frac{r}{R_E}+\frac{r^2}{R_E^2}+\frac{r^3}{R_E^3}$ (b) $1-\frac{r}{R_E}-\frac{r^2}{R_E^2}-\frac{r^3}{R_E^3}$
(c) $1+\frac{r}{R_E}-\frac{r^2}{R_E^2}-\frac{r^3}{R_E^3}$ (d) $1+\frac{r}{R_E}-\frac{r^2}{R_E^2}+\frac{r^3}{R_E^3}$

52. Match List - I with List - II. **[18 March, 2021 (Shift-I)]**

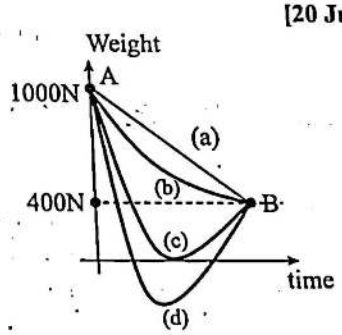
List-I		List-II	
A.	10 km height over earth's surface	I.	Thermosphere
B.	70 km height over earth's surface	II.	Mesosphere
C.	180 km height over earth's surface	III.	Stratosphere
D.	270 km height over earth's surface	IV.	Troposphere

Choose the correct answer from the options given below:
(a) A → II; B → I; C → IV; D → III
(b) A → IV; B → III; C → II; D → I
(c) A → III; B → II; C → I; D → IV
(d) A → I; B → IV; C → III; D → II

53. A body weighs 49 N on a spring balance at the north pole. What will be its weight recorded on the same weighing machine, if it is shifted to the equator? [use $g = \frac{Gm}{R^2} = 9.8$ ms⁻² and radius of earth, R = 6400 km]. **[24 Feb, 2021 (Shift-II)]**
(a) 49.83 N (b) 48.83 N (c) 49 N (d) 49.17 N

54. Consider a planet in some solar system which has a mass double the mass of earth and density equal to the average density of earth. If the weight of an object on earth is W, the weight of the same object on that planet will be: **[25 July, 2021 (Shift-II)]**
(a) $2W$ (b) W (c) $\sqrt{2}W$ (d) $2^{\frac{1}{3}}W$

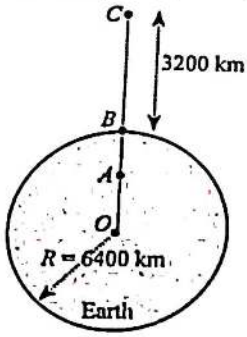
55. A person whose mass is 100 kg travels from Earth to Mars in a spaceship. Neglect all other object in sky and take acceleration due to gravity on the surface of the Earth and mars as 10m/s² and 4m/s² respectively. Identify from the below figures, the curve that fits best for the weight of the passenger as a function of time. **[20 July, 2021 (Shift-I)]**



(a) (c) (b) (a) (c) (b) (d) (d)

@FAKE_JEE_X_GRINDER_BOT

56. In the reported figure of earth, the value of acceleration due to gravity is same at point A and C but it is smaller than that of its value at point B (surface of the earth). The value of $OA : AB$ will be $x : y$. The value of x is _____. **[26 Feb, 2021 (Shift-II)]**



57. A box weights 196 N on a spring balance at the north pole. Its weight recorded on the same balance if it is shifted to the equator is close to (Take $g = 10\ ms^{-2}$ at the north pole and the radius of the earth = 6400 km) **[7 Jan, 2020 (Shift-II)]**
(a) 194.66 N (b) 195.66 N (c) 195.32 N (d) 194.32 N

58. The value of the acceleration due to gravity is g, at a height $h = \frac{R}{2}$ (R = radius of the earth) from the surface of the earth. It is again equal to g, at a depth d below the surface of the earth. The ratio $\left(\frac{d}{R}\right)$ equals **[5 Sep, 2020 (Shift-I)]**
(a) $\frac{5}{9}$ (b) $\frac{1}{3}$ (c) $\frac{7}{9}$ (d) $\frac{4}{9}$

59. The height 'h' at which the weight of a body will be the same as that at the same depth 'h' from the surface of the earth is (Radius of the earth is R and effect of the rotation of the earth is neglected) **[2 Sep, 2020 (Shift-II)]**
(a) $\frac{\sqrt{5}R-R}{2}$ (b) $\frac{\sqrt{3}R-R}{2}$ (c) $\frac{R}{2}$ (d) $\frac{\sqrt{5}}{2}R-R$

60. The acceleration due to gravity on the earth's surface at the poles is g and angular velocity of the earth about the axis passing through the pole is ω. An object is weighed at the equator and at a height h above the poles by using a spring balance. If the weights are found to be same, then h is ($h << R$, where R is the radius of the earth) **[5 Sep, 2020 (Shift-II)]**
(a) $\frac{R^2\omega^2}{2g}$ (b) $\frac{R^2\omega^2}{g}$ (c) $\frac{R^2\omega^2}{8g}$ (d) $\frac{R^2\omega^2}{4g}$

61. The value of acceleration due to gravity at Earth's surface is 9.8 ms^{-2}. The altitude above its surface at which the acceleration due to gravity decreases to 4.9 ms^{-2}, is close to: (Radius of earth = 6.4×10^6 m) **[10 April, 2019 (Shift-I)]**
(a) 1.6×10^6 m (b) 6.4×10^6 m
(c) 9.0×10^6 m (d) 2.6×10^6 m

Gravitational PE, Escape velocity

62. The gravitational potential at a point above the surface of earth is -5.12×10^7 J/kg and the acceleration due to gravity at that point is 6.4 m/s^2. Assume that the mean radius of earth to be 6400 km. The height of this point above the earth's surface is: **[30 Jan, 2024 (Shift-I)]**
(a) 1600 km (b) 540 km (c) 1200 km (d) 1000 km

63. The mass of the moon is 1/144 times the mass of a planet and its diameter 1/16 times the diameter of a planet. If the escape velocity on the planet is v, the escape velocity on the moon will be: **[31 Jan, 2024 (Shift-II)]**
(a) $\frac{v}{3}$ (b) $\frac{v}{4}$ (c) $\frac{v}{12}$ (d) $\frac{v}{6}$

64. Escape velocity of a body from earth is 11.2 km/s. If the radius of a planet be one-third the radius of earth and mass be one-sixth that of earth, the escape velocity from the plate is: **[30 Jan, 2024 (Shift-II)]**
(a) 11.2 km/s (b) 8.4 km/s (c) 4.2 km/s (d) 7.9 km/s

65. An astronaut takes a ball of mass m from earth to space. He throws the ball into a circular orbit about earth at an altitude of 318.5 km. From earth's surface to the orbit, the change in total mechanical energy of the ball is $x\frac{GM_em}{21R_e}$. The value of x is (take R_e = 6370 km): **[09 April, 2024 (Shift-I)]**
(a) 11 (b) 9 (c) 12 (d) 10

66. To project a body of mass m from earth's surface to infinity, the required kinetic energy is (assume, the radius of earth is R_e, g = acceleration due to gravity on the surface of earth): **[06 April, 2024 (Shift-I)]**
(a) $2mgR_E$ (b) mgR_E (c) $\frac{1}{2}mgR_E$ (d) $4\ mgR_E$

67. Match list-I with list-II:

	List-I		List-II
A.	Kinetic energy of planet	I.	$\frac{-GMm}{a}$
B.	Gravitation Potential energy of Sun-planet system	II.	$\frac{GMm}{2a}$
C.	Total mechanical energy of planet	III.	$\frac{Gm}{r}$
D.	Escape energy at the surface of planet for unit mass object	IV.	$-\frac{GMm}{2a}$

(Where a = radius of planet orbit, r = radius of planet, M = mass of Sun, m = mass of planet)
Choose the correct answer from the options given below: **[05 April, 2024 (Shift-I)]**
(a) A → II; B → I; C → IV; D → III
(b) A → III; B → IV; C → I; D → II
(c) A → I; B → IV; C → II; D → III
(d) A → I; B → II; C → III; D → IV

68. Given below are two statements :
Statement-I: For a planet, if the ratio of mass of the planet to its radius increases, the escape velocity from the planet also increases.
Statement-II: Escape velocity is independent of the radius of the planet.
In the light of above statements, choose the ***most appropriate*** answer from the options given below **[13 April, 2023 (Shift-II)]**
(a) Both Statement-I and Statement-II are incorrect
(b) Statement-I is correct but Statement-II is incorrect
(c) Statement-I is incorrect but Statement-II is correct
(d) Both Statement-I and Statement-II are correct

@FAKE_PAGE_X @RAJ_DUNE

69. If earth has a mass nine times and radius twice that of a planet P. Then $\frac{v_e}{3}\sqrt{x}\,ms^{-1}$ will be the minimum velocity required by a rocket to pull out of gravitational force of P, where v_e is escape velocity on earth. The value of x is [1 Feb, 2023 (Shift-I)]
(a) 2 (b) 3 (c) 18 (d) 1

70. If V is the gravitational potential due to sphere of uniform density on it's surface, then it's value at the center of sphere will be:
[11 April, 2023 (Shift-II)]
(a) $\frac{3V}{2}$ (b) V (c) $\frac{4}{3}V$ (d) $\frac{V}{2}$

71. A planet having mass 9 M_e and radius 4 R_e, where M_e and R_e are mass and radius of earth respectively, has escape velocity in km/s given by [13 April, 2023 (Shift-I)]
(Given escape velocity on earth $v_e = 11.2 \times 10^3$ m/s)
(a) 67.2 (b) 16.8 (c) 33.6 (d) 11.2

72. A body is released from a height equal to the radius (R) of the earth. The velocity of the body when it strikes the surface of the earth will be:
(Given g = acceleration due to gravity on the earth.)
[15 April, 2023 (Shift-I)]
(a) $\sqrt{gR}$ (b) $\sqrt{4gR}$ (c) $\sqrt{2gR}$ (d) $\sqrt{\frac{gR}{2}}$

73. A spaceship of mass 2×10^4 kg is launched into a circular orbit close to the earth surface. The additional velocity to be imparted to the spaceship in the orbit to overcome the gravitational pull will be (if $g = 10$ m/s^2 and radius of earth = 6400 km)
[11 April, 2023 (Shift-2)]
(a) $11.2\left(\sqrt{2}-1\right)km/s$ (b) $7.9\left(\sqrt{2}-1\right)km/s$
(c) $8\left(\sqrt{2}-1\right)km/s$ (d) $7.4\left(\sqrt{2}-1\right)km/s$

74. Given below are two statements : one is labelled as **Assertion A** and the other is labelled as **Reason R**.
Assertion (A): Earth has atmosphere whereas moon doesn't have any atmosphere.
Reason (R): The escape velocity on moon is very small as compared to that on earth.
In the light of the above statement, choose the correct answer from the options given below: [6 April, 2023 (Shift-I)]
(a) A is true but R is false
(b) A is false but R is true
(c) Both A and R are correct but R is NOT the correct explanation of A
(d) Both A and R are correct and R is correct explanation of A

75. The escape velocities of two planets A and B are in the ratio 1 : 2. If the ratio of their radii respectively is 1 : 3, then the ratio of acceleration due to gravity of planet A to the acceleration of gravity of planet B will be: [1 Feb, 2023 (Shift-II)]
(a) $\frac{4}{3}$ (b) $\frac{3}{2}$ (c) $\frac{2}{3}$ (d) $\frac{3}{4}$

76. A body of mass m is taken from the earth surface to a height h equal to twice the radius of earth (R_e), the increase in potential energy will be: (g = acceleration due to gravity on the surface of Earth)
[25 Jan, 2023 (Shift-II)]
(a) $3mgRe$ (b) $\frac{1}{3}mgR_e$ (c) $\frac{2}{3}mgR_e$ (d) $\frac{1}{2}mgR_e$

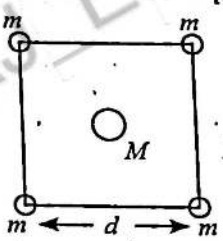
77. If the gravitational field in the space is given as $\left(-\frac{K}{r^2}\right)$. Taking the reference point to be at $r = 2$ cm with gravitational potential $V = 10$ J/kg. Find the gravitational potential at $r = 3$cm in SI unit (Given, that $K = 6$ J cm/kg) [30 Jan, 2023 (Shift-I)]
(a) 9 (b) 11 (c) 12 (d) 10

78. An object is allowed to fall from a height R above the earth, where R is the radius of earth. Its velocity when it strikes the earth's surface, ignoring air resistance, will be [30 Jan, 2023 (Shift-II)]
(a) $2\sqrt{gR}$ (b) $\sqrt{gR}$ (c) $\sqrt{\frac{gR}{2}}$ (d) $\sqrt{2gR}$

79. The ratio of escape velocity of a planet to the escape velocity of earth will be:
Given: Mass of the planet is 16 times mass of earth and radius of the planet is 4 times the radius of earth. [12 April, 2023 (Shift-I)]
(a) 4 : 1 (b) 2 : 1 (c) 1 : $\sqrt{2}$ (d) 1 : 4

80. An object of mass 1 kg is taken to a height from the surface of earth which is equal to three times that radius of earth. The gain in potential energy of the object will be [If, g = 100 ms^{-2} and radius of earth = 6400 km] [29 July, 2022 (Shift-II)]
(a) 48 MJ (b) 24 MJ (c) 36 MJ (d) 12 MJ

81. Four spheres each of mass m form a square of side d (as shown in figure). A fifth sphere of mass M is situated at the centre of square. The total gravitational potential energy of the system is: [27 June, 2022 (Shift-II)]



(a) $-\frac{Gm}{d}\left[(4+\sqrt{2})m+4\sqrt{2}M\right]$
(b) $-\frac{Gm}{d}\left[(4+\sqrt{2})M+4\sqrt{2}m\right]$
(c) $-\frac{Gm}{d}\left[3m^2+4\sqrt{2}M\right]$
(d) $-\frac{Gm}{d}\left[6m^2+4\sqrt{2}M\right]$

82. A body of mass m is projected with velocity λv_e in vertically upward direction from the surface of the earth into space. It is given that v_e is escape velocity and $\lambda < 1$. If air resistance is considered to be negligible, then the maximum height from the centre of earth, to which the body can go, will be:
(R: radius of earth) [27 July, 2022 (Shift-II)]
(a) $\frac{R}{1+\lambda^2}$ (b) $\frac{R}{1-\lambda^2}$ (c) $\frac{R}{1-\lambda}$ (d) $\frac{\lambda^2 R}{1-\lambda^2}$

83. A body is projected vertically upward from the surface of earth with a velocity equal to one third of escape velocity. The maximum height attained by the body will be:
(Take radius of earth = 6400 km and g = 10 ms^{-2})
[26 July, 2022 (Shift-II)]
(a) 800 km (b) 1600 km (c) 2133 km (d) 4800 km

@RAKESH_EDUCARE_CBSE_X

84. Two spherical stars A and B have densities r_A and r_B, respectively. A and B have the same radius, and their masses M_A and M_B are related by $M_B = 2M_A$. Due to an interaction process, star A loses some of its mass, so that its radius is halved, while its spherical shape is retained, and its density remains ρ_A. If v_A and v_B are the escape velocities from A and B after interaction process, the ratio $\frac{v_B}{v_A} = \sqrt{\frac{10n}{15^{1/3}}}$.

The value of n is _____. [JEE Adv, 2022]

85. A mass of 50 kg is placed at the centre of a uniform spherical shell of mass 100 kg and radius 50 m. If the gravitational potential at a point, 25 m from the centre is V kg/m. The value of V is:

[27 Aug, 2021 (Shift-II)]

(a) +2 G (b) −4 G (c) −20 G (d) −60 G

86. A body is projected vertically upwards from the surface of earth with a velocity sufficient enough to carry it to infinity. The time taken by it to reach height h is_____s. [22 July, 2021 (Shift-II)]

(a) $\sqrt{\frac{2R_e}{g}}\left[\left(1+\frac{h}{R_e}\right)^{3/2}-1\right]$ (b) $\frac{1}{3}\sqrt{\frac{2R_e}{g}}\left[\left(1+\frac{h}{R_e}\right)^{3/2}-1\right]$

(c) $\frac{1}{3}\sqrt{\frac{R_e}{2g}}\left[\left(1+\frac{h}{R_e}\right)^{3/2}-1\right]$ (d) $\sqrt{\frac{R_e}{2g}}\left[\left(1+\frac{h}{R_e}\right)^{3/2}-1\right]$

87. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.

Assertion (A): The escape velocities of planet A and B are same. But A and B are of unequal mass.

Reason (R): The product of their mass and radius must be same. $M_1R_1 = M_2R_2$

In the light of the above statements, choose the most appropriate answer from the options given below: [25 Feb, 2021 (Shift-I)]

(a) A is correct but R is not correct
(b) Both A and R are correct but R is NOT the correct explanation of A
(c) Both A and R are correct and R is the correct explanation of A
(d) A is not correct but R is correct

88. The masses and radii of the earth and moon are (M_1, R_1) and (M_2, R_2) respectively. Their centres are at a distance 'r' apart. Find the minimum escape velocity for a particle of mass 'm' to be projected from the middle of these two masses: [31 Aug, 2021 (Shift-I)]

(a) $v=\frac{1}{2}\sqrt{\frac{4G(M_1+M_2)}{r}}$ (b) $v=\sqrt{\frac{4G(M_1+M_2)}{r}}$

(c) $v=\frac{\sqrt{2G}(M_1+M_2)}{r}$ (d) $v=\frac{1}{2}\sqrt{\frac{2G(M_1+M_2)}{r}}$

89. Inside a uniform spherical shell : [26 Aug, 2021 (Shift-I)]

(A) the gravitational field is zero
(b) the gravitational potential is zero
(c) the gravitational field is same everywhere
(d) the gravitation potential is same everywhere
(e) all the above

Choose the most appropriate answer from the options given below :

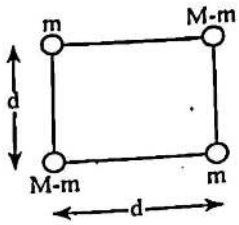
(a) (e) only (b) (a), (c) and (d) only
(c) (b), (c) and (d) only (d) (a), (b) and (c) only

90. The radius in kilometre to which the present radius of earth (R = 6400 km) to be compressed so that the escape velocity is increased 10 times is [17 March, 2021 (Shift-I)]

91. The initial velocity v_i required to project a body vertically upward from the surface of the earth to reach a height of $10R$, where R is the radius of the earth, may be described in terms of escape v_e velocity such that $v_i = \sqrt{\frac{x}{y}} \times v_e$.

The value of x will be _____. [25 Feb, 2021 (Shift-II)]

92. A body of mass (2M) splits into four masses {m, M−m, m, M−m}, which are rearranged to form a square as shown in the figure. The ratio of $\frac{M}{m}$ for which, the gravitational potential energy of the system becomes maximum is x : 1. The value of x is [27 Aug, 2021 (Shift-I)]



93. If one wants to remove all the mass of the earth to infinity in order to break it up completely.

The amount of energy that needs to be supplied will be $\frac{xGM^2}{5R}$ where x is _____. (Round off to the Nearest Integer) (M is the mass of earth, R is the radius of earth, G is the gravitational constant) [16 March, 2021 (Shift-II)]

94. A body A of mass m is moving in a circular orbit of radius R about a planet. Another body B of mass $\frac{m}{2}$ collides with A with a velocity which is half $\left(\frac{\vec{v}}{2}\right)$ the instantaneous velocity $\vec{v}$ of A. The collision is completely inelastic. Then, the combined body:

[9 Jan, 2020 (Shift-I)]

(a) Starts moving in an elliptical orbit around the planet.
(b) Continues to move in a circular orbit.
(c) Escapes from the Planet's Gravitational field.
(d) Falls vertically downwards towards the planet.

95. On the x-axis and at a distance x from the origin, the gravitational field due to a mass distribution is given by $\frac{Ax}{(x^2+a^2)^{3/2}}$ in the x-direction. The magnitude of gravitational potential on the x-axis at a distance x, taking its value to be zero at infinity, is [4 Sep, 2020 (Shift-I)]

(a) $A(x^2+a^2)^{3/2}$ (b) $\frac{A}{(x^2+a^2)^{3/2}}$

(c) $\frac{A}{(x^2+a^2)^{1/2}}$ (d) $A(x^2+a^2)^{1/2}$

96. Two planets have masses M and $16M$ and their radii are a and $2a$, respectively. The separation between the centres of the planets is $10a$. A body of mass m is fired from the surface of the larger planet towards the smaller planet along the line joining their centres. For the body to be able to reach at the surface of smaller planet, the minimum firing speed needed is [6 Sep, 2020 (Shift-II)]

(a) $\frac{3}{2}\sqrt{\frac{5GM}{a}}$ (b) $\sqrt{\frac{GM^2}{ma}}$ (c) $2\sqrt{\frac{GM}{a}}$ (d) $4\sqrt{\frac{GM}{a}}$

@FREE CBSE X @RAJEDUNET

97. Planet A has mass M and radius R. Planet B has half the mass and half the radius of Planet A. If the escape velocities from the Planets A and B are V_A and V_B, respectively, then $V_A/V_B = n/4$. The value of n is
[9 Jan, 2020 (Shift-II)]
(a) 3 (b) 2 (c) 1 (d) 4

98. A body is moving in a low circular orbit about a planet of mass M and radius R. The radius of the orbit can be taken to be R itself. Then the ratio of the speed of this body in the orbit to the escape velocity from the planet is
[4 Sep, 2020 (Shift-II)]
(a) 1 (b) $\sqrt{2}$ (c) 2 (d) $\frac{1}{\sqrt{2}}$

99. An asteroid is moving directly towards the centre of the earth. When at a distance of $10R$ (R is the radius of the earth) from the earths centre, it has a speed of 12 km/s. Neglecting the effect of earths atmosphere, what will be the speed of the asteroid when it hits the surface of the earth (escape velocity from the earth is 11.2 km/s)? Give your answer to the nearest integer in kilometer/s
[8 Jan, 2020 (Shift-II)]

100. Two stars of masses 3×10^{31} kg each, and at distance 2×10^{11} m rotate in a plane about their common centre of mass O. A meteorite passes through O moving perpendicular to the star's rotation plane. In order ot escape from the gravitational field of this double star, the minimum speed that meteorite should have at O is (Take Gravitational constant $G = 6.67 \times 10^{-11}$ Nm^2 kg^{-2})
[10 Jan, 2019 (Shift-II)]
(a) 2.4×10^4 m/s (b) 1.4×10^5 m/s
(c) 3.8×10^4 m/s (d) 2.8×10^5 m/s

101. A rocket has to be launched from earth in such a way that it never returns. If E is the minimum energy delivered by the rocket launcher, what should be the minimum energy that the launcher should be the minimum energy that the launcher should have if the same rocket is to be launched from the surface of the moon? Assume that the density of the earth and the moon are equal and that the earth's volume is 64 times the volume of the moon
[8 April, 2019 (Shift-II)]
(a) $\frac{E}{4}$ (b) $\frac{E}{16}$ (c) $\frac{E}{32}$ (d) $\frac{E}{64}$

Satellite Motion

102. Two planets A and B having masses m_1 and m_2 move around the sun in circular orbits of r_1 and r_2 radii respectively. If angular momentum of A is L and that of B is $3L$, the ratio of time period $\left(\frac{T_A}{T_B}\right)$ is:
[08 April, 2024 (Shift-I)]
(a) $\left(\frac{r_2}{r_1}\right)^{3/2}$ (b) $\left(\frac{r_1}{r_2}\right)^3$ (c) $\frac{1}{27}\left(\frac{m_2}{m_1}\right)^3$ (d) $27\left(\frac{m_1}{m_2}\right)^3$

103. A satellite of 10^3 kg mass is revolving in circular orbit of radius $2R$. If $\frac{10^4 R}{6} J$ energy is supplied to the satellite, it would revolve in a new circular orbit of radius:
[09 April, 2024 (Shift-II)]
(use $g = 10$ m/s^2, R = radius of earth)
(a) 2.5 R (b) 3 R (c) 4 R (d) 6 R

104. Two satellite A and B go round a planet in circular orbits having radii $4R$ and R respectively. If the speed of A is $3v$, the speed of B will be:
[08 April, 2024 (Shift-II)]
(a) $\frac{4}{3}v$ (b) $3v$ (c) $6v$ (d) $12v$

105. A satellite revolving around a planet in stationary orbit has time period 6 hours. The mass of planet is one-fourth the mass of earth. The radius orbit of planet is: (Given = Radius of geo-stationary orbit for earth is 4.2×10^4 km)
[05 April, 2024 (Shift-II)]
(a) 1.4×10^4 km (b) 8.4×10^4 km
(c) 1.68×10^4 km (d) 1.05×10^4 km

106. Correct formula for height of a satellite from earths surface is:
[04 April, 2024 (Shift-II)]
(a) $\left(\frac{T^2R^2g}{4\pi}\right)^{1/3} - R$ (b) $\left(\frac{T^2R^2g}{4\pi^2}\right)^{1/3} - R$
(c) $\left(\frac{T^2R^2}{4\pi^2g}\right)^{1/3} - R$ (d) $\left(\frac{T^2R^2}{4\pi^2}\right)^{-1/3} + R$

107. Two satellites A and B move round the earth in the same orbit. The mass of A is twice the mass of B.
The quantity which is same for the two satellites will be:
[12 April, 2023 (Shift-I)]
(a) Potential energy (b) Total enegy
(c) Kinetic energy (d) Speed

108. The time period of a satellite, revolving above earth's surface at a height equal to R will be
(Given $g = \pi^2$ m/s^2, R = radius of earth)
[10 April, 2023 (Shift-II)]
(a) $\sqrt{4R}$ (b) $\sqrt{8R}$ (c) $\sqrt{32R}$ (d) $\sqrt{2R}$

109. The orbital angular momentum of a satellite is L, when it is revolving in a circular orbit at height h from earth surface. If the distance of satellite from the earth centre is increased by eight times to its initial value, then the new angular momentum will be-
[8 April, 2023 (Shift-II)]
(a) $8L$ (b) $4L$ (c) $9L$ (d) $3L$

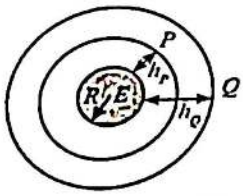
110. Choose the incorrect statement from the following:
[6 April, 2023 (Shift-II)]
(a) The speed of satellite in a given circular orbit remains constant.
(b) For a planet revolving around the sun in an elliptical orbit, the total energy of the planet remains constant.
(c) When a body fall towards earth, the displacement of earth towards the body is negligible.
(d) The linear speed of a planet revolving around the sun remains constant.

111. Given below are two statements:
Statement-I: If E be the total energy of a satellite moving around the earth, then its potential energy will be $\frac{E}{2}$.
Statement-II: The kinetic energy of a satellite revolving in an orbit is equal to the half the magnitude of total energy E.
In the light of the above statements, choose the most appropriate answer from the options given below [8 April, 2023 (Shift-I)]
(a) Both Statement-I and Statement-II are correct
(b) Both Statement-I and Statement-II are incorrect
(c) Statement-I is incorrect but Statement-II is correct
(d) Statement-I is correct but Statement-II is incorrect

112. Two satellites of masses m and 3 m revolve around the earth in circular orbits of radii r & SS3r respectively. The ratio of orbital speeds of the satellites respectively is: [10 April, 2023 (Shift-I)]
(a) 1 : 1 (b) 3 : 1 (c) $\sqrt{3}$: 1 (d) 9 : 1

@FIITJEE_CBSE_NTSE_OLYMPIAD_NET

113. Two satellites P and Q are moving in different circular orbits around the Earth (radius R). The heights of P and Q from the Earth surface are h_P and h_Q, respectively, where $h_P = R/3$. The accelerations of P and Q due to Earth's gravity are g_P and g_Q, respectively. If $g_P/g_Q = 36/25$, what is the value of h_Q? **[JEE Adv, 2023]**



(a) $3R/5$ (b) $R/6$ (c) $6R/5$ (d) $5R/6$

114. Two satellites S_1 and S_2 are revolving in circular orbits around a planet with radius $R_1 = 3200$ km and $R_2 = 800$ km respectively. The ratio of speed of satellite S_1 to the speed of satellite S_2 in their respective orbits would be $1/x$ where $x =$ **[25 June, 2022 (Shift-II)]**

115. Suppose two planets (spherical in shape) of radii R and $2R$, but mass M and $9M$ respectively have a centre to centre separation $8R$ as shown in the figure. A satellite of mass 'm' is projected from the surface of the planet of mass 'M' directly towards the centre of the second planet. The minimum speed 'υ' required for the satellite to reach the surface of the second plant is a $\sqrt{\frac{a}{7}\frac{GM}{R}}$ then the value of 'a' is _____.

116. The mass density of a spherical galaxy varies as $\frac{K}{r}$ over a large distance 'r' from it s centre. In that region, a small star is in a circular orbit of radius R. Then the period of revolution, T depends on R as **[2 Sep, 2020 (Shift-I)]**

(a) $T^2 \propto \frac{1}{R^3}$ (b) $T^2 \propto R$ (c) $T \propto R$ (d) $T^2 \propto R^3$

117. A satellite is moving in a low nearly circular orbit around the earth. Its radius is roughly equal to that of the earth's radius R_e. By firing rockets attached to it, its speed is instantaneously increased in the direction of its motion so that it become $\sqrt{\frac{3}{2}}$ times larger. Due to this the farthest distance from the centre of the earth that the satellite reaches is R. Value of R is **[3 Sep, 2020 (Shift-I)]**

(a) $3Re$ (b) $4Re$ (c) $2.5Re$ (d) $2Re$

118. A spaceship in space sweeps stationary interplanetary dust. As a result, its mass increases at a rate $\frac{dM(t)}{dt} = bv^2(t)$, where $v(t)$ is its instantaneous velocity. The instantaneous acceleration of the satellite is **[5 Sep, 2020 (Shift-II)]**

(a) $-bv^3$ (b) $-\frac{2bv^3}{M(t)}$

(c) $-\frac{bv^3}{M(t)}$ (d) $-\frac{bv^3}{2M(t)}$

9. A satellite is in an elliptical orbit around a planet P. It is observed that the velocity of the satellite when it is farthest from the planet is 6 times of that when it is closest to the planet. The ratio of distances between the satellite and the planet at closest and farthest points is **[6 Sep, 2020 (Shift-I)]**

(a) 1 : 6 (b) 1 : 2 (c) 3 : 4 (d) 1 : 3

120. A satellite of mass M is launched vertically upwards with an initial speed u from the surface of the earth. After it reaches height R (R = radius of the earth), it ejects a rocket of mass $\frac{M}{10}$ so that subsequently the satellite moves in a circular orbit. The kinetic energy of the rocket is (G is the gravitational constant; M_e is the mass of the earth) **[7 Jan, 2020 (Shift-I)]**

(a) $\frac{M}{20}\left(u^2 - \frac{113}{200}\frac{GM_e}{R}\right)$ (b) $5M\left(u^2 - \frac{119}{200}\frac{GM_e}{R}\right)$

(c) $\frac{3M}{8}\left(u + \sqrt{\frac{5GM_e}{6R}}\right)^2$ (d) $\frac{M}{2}\left(u - \sqrt{\frac{2GM_e}{3R}}\right)^2$

121. A spaceship orbits around a planet at a height of 20 km from its surface. Assuming that only gravitational field of the planet acts on the spaceship, what will be the number of complete revolutions made by the spaceship in 24 hours around the planet?
[Given: Mass of planet = 8×10^{22} kg;
Radius of planet = 2×10^6 m,
Gravitational constant $G = 6.67 \times 10^{-11}$ Nm^2/ kg^2]
[10 April, 2019 (Shift-II)]

(a) 9 (b) 11 (c) 13 (d) 17

122. A satellite is revolving in a circular orbit at a height 'h' from the earth's surface (radius of earth R; $h << R$). The minimum increase in its orbital velocity required, so that the satellite could escape from the earth's gravitational field, is close to: (Neglect the effect of atmosphere.) **[11 Jan, 2019 (Shift-I)]**

(a) $\sqrt{2gr}$ (b) $\sqrt{gr}$

(c) $\sqrt{gr/2}$ (d) $\sqrt{gr}(\sqrt{2}-1)$

123. The energy required to take a satellite to a height 'h' above Earth surface (radius of Earth = 6.4×10^3 km) is E_1 and kinetic energy required for the satellite to be in a circular orbit at this height is E_2. The value of h for which E_1 and E_2 are equal is **[9 Jan, 2019 (Shift-II)]**

(a) 1.6×10^3 km (b) 3.2×10^3 km

(c) 6.4×10^3 km (d) 1.28×10^4 km

124. Two satellites, A and B, have masses m and $2m$ respectively. A is in a circular orbit of radius R, and B is in a circular orbit of radius $2R$ around the earth. The ratio of their kinetic energies, T_A/T_B is **[12 Jan, 2019 (Shift-II)]**

(a) $\frac{1}{2}$ (b) 1 (c) 2 (d) $\sqrt{\frac{1}{2}}$

125. A satellite is moving with a constant speed v in circular orbit around the earth. An object of mass 'm' is ejected from the satellite such that it just escapes from the gravitational pull of the earth. At the time of ejection, the kinetic energy of the object is **[10 Jan, 2019 (Shift-I)]**

(a) $2mv^2$ (b) mv^2 (c) $\frac{1}{2}mv^2$ (d) $\frac{3}{2}mv^2$

126. A satellite of mass M is in a circular orbit of radius R about the centre of the earth. A meteorite of the same mass, falling towards the earth collides with the satellite completely inelastically. Their speeds of the satellite and the meteorite are the same, just before the collision. The subsequent motion of the combined body will be **[12 Jan, 2019 (Shift-I)]**

(a) Such that it escapes to infinity
(b) In an elliptical orbit
(c) In the same circular orbit of radius R
(d) In a circular orbit of a different radius

@TAKE_CBSE_@_LEDUNE

Kepler's Laws, Binary Stars

127. A planet takes 200 days to complete one revolution around the Sun. If the distance of the planet from Sun is reduced to one fourth of the original distance, how many days will it take to complete one revolution? **[29 Jan, 2024 (Shift-II)]**

128. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A): The angular speed of the moon in its orbit about the earth is more than the angular speed of the earth in its orbit about the sun.

Reason (R): The moon takes less time to move around the earth than the time taken by the earth to move around the sun.

In the light of the above statements, choose the most appropriate answer from the options given below: **[27 Jan, 2024 (Shift-II)]**

(a) (A) is correct but (R) is not correct
(b) Both (A) and (R) are correct and (R) is the correct explanation of (A)
(c) Both (A) and (R) are correct but (R) is not the correct explanation of (A)
(d) (A) is not correct but (R) is correct

129. A light planet is revolving around a massive star in a circular orbit of radius R with a period of revolution T. If the force of attraction between planet and star is proportional to $R^{-3/2}$ then choose the correct option: **[1 Feb, 2024 (Shift-II)]**

(a) $T^2 \propto R^{5/2}$ (b) $T^2 \propto R^{7/2}$
(c) $T^2 \propto R^{3/2}$ (d) $T^2 \propto R^3$

130. If the distance of the earth from Sun is 1.5×10^6 km. Then the distance of an imaginary planet from Sun, if its period of revolution is 2.83 years is: **[24 Jan, 2023 (Shift-II)]**

(a) 6×10^7 km (b) 6×10^6 km
(c) 3×10^6 km (d) 3×10^7 km

131. The time period of a satellite of earth is 24 hours. If the separation between the earth and the satellite is decreased to one fourth of the previous value, then its new time period will be, **[29 Jan, 2023 (Shift-II)]**

(a) 4 hours (b) 6 hours (c) 12 hours (d) 3 hours

132. Every planet revolves around the sun in an elliptical orbit:

A. The force acting on a planet is inversely proportional to square of the distance from the sun.

B. Force acting on a planet is inversely proportional to the product of the masses of the planet and the sun C.

C. The centripetal force acting on the planet is directed away from the sun.

D. The square of time period of revolution of planet around sun is directly proportional to cube of semi-major axis of elliptical orbit.

Choose the correct answer from the options given below: **[25 Jan, 2023 (Shift-II)]**

(a) A and D only (b) C and D only
(c) B and C only (d) A and C only

133. The distance between Sun and Earth is R. The duration of year if the distance between Sun and Earth becomes $3R$ will be **[24 June, 2022 (Shift-II)]**

(a) $\sqrt{3}$ years (b) 3 years
(c) 9 years (d) $3\sqrt{3}$ years

134. Two planets A and B of equal mass are having their period of revolutions T_A and T_B such that $T_A = 2T_B$. These planets are revolving in the circular orbits of radii r_A and r_B respectively. Which out of the following would be the correct relationship of their orbits? **[28 June, 2022 (Shift-I)]**

(a) $2r_A^2 = r_B^3$ (b) $r_A^3 = 2r_B^3$
(c) $r_A^3 = 4r_B^3$ (d) $T_A^2 - T_B^2 = \frac{\pi^2}{GM}(r_B^3 - 4r_A^3)$

135. The time period of a satellite revolving around earth in a given orbit is 7 hours. If the radius of orbit is increased to three its previous value, then approximate new time period of the satellite will be **[29 June, 2022 (Shift-II)]**

(a) 40 hours (b) 36 hours (c) 30 hours (d) 25 hours

136. Two stars of masses m and $2m$ at a distance d rotate about their common centre of mass in free space. The period of revolution is: **[24 Feb, 2021 (Shift-I)]**

(a) $2\pi\sqrt{\frac{3Gm}{d^3}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{3Gm}{d^3}}$
(c) $2\pi\sqrt{\frac{d^3}{3Gm}}$ (d) $\frac{1}{2\pi}\sqrt{\frac{d^3}{3Gm}}$

137. The maximum and minimum distances of a comet from the Sun are 1.6×10^{12} m and 8.0×10^{10} m respectively. If the speed of the comet at the nearest point is 6×10^4 ms^{-1}, the speed at the farthest point is: **[16 March, 2021 (Shift-I)]**

(a) 3.0×10^3 m/s (b) 1.5×10^3 m/s
(c) 4.5×10^3 m/s (d) 6.0×10^3 m/s

138. The time period of satellite in a circular orbit of radius R is T. The period of another satellite in a circular orbit of radius 9R is: **[18 March, 2021 (Shift-I)]**

(a) 12 T (b) 9 T (c) 27 T (d) 3 T

139. Consider two satellites S_1 and S_2 with periods of revolution 1 hr. and 8 hr. respectively revolving around a planet in circular orbits. The ratio of angular velocity of satellite S_1 to the angular velocity of satellites S_2 is: **[24 Feb, 2021 (Shift-I)]**

(a) 1:8 (b) 1:4 (c) 2:1 (d) 8:1

140. The planet Mars has two moons, if one of them has a period 7 hours, 30 minutes and an orbital radius of 9.0×10^3 km. Find the mass of Mars. **[27 July, 2021 (Shift-II)]**

$\left\{Given \frac{4\pi^2}{G} = 6 \times 10^{11}\ N^{-2}\ kg^2\right\}$

(a) 3.25×10^{21} kg (b) 6.00×10^{23} kg
(c) 5.96×10^{19} kg (d) 7.02×10^{25} kg

141. The minimum and maximum distances of a planet revolving around the Sun are x_1 and x_2. If the minimum speed of the planet on its trajectory is v_0 then its maximum speed will be: **[25 July, 2021 (Shift-I)]**

(a) $\frac{v_0 x_1^2}{x_2^2}$ (b) $\frac{v_0 x_2^2}{x_1^2}$
(c) $\frac{v_0 x_2}{x_1}$ (d) $\frac{v_0 x_1}{x_2}$

142. The angular momentum of a planet of mass M moving around the sun in an elliptical orbit is $\vec{L}$. The magnitude of the areal velocity of the planet is: **[18 March, 2021 (Shift-II)]**

(a) $\frac{2L}{M}$ (b) $\frac{L}{2M}$ (c) $\frac{4L}{M}$ (d) $\frac{L}{M}$

@JEE_ADVANCED_RAJ_BHOPAL

143. A planet revolving in elliptical orbit has: [26 Feb, 2021 (Shift-I)]

A. a constant velocity of revolution.

B. has the least velocity when it is nearest to the sun.

C. its areal velocity is directly proportional to its velocity.

D. areal velocity is inversely proportional to its velocity.

E. To follow a trajectory such that the areal velocity is constant.

Choose the correct answer from the options given below:

(a) C only (b) A only

(c) D only (d) E only

144. Consider a binary star system of star A and star B with masses m_A and m_B revolving in a circular orbit of radii r_A and r_B, respectively. If T_A and T_b are the time period of star A and star B, respectively, then: [20 July, 2021 (Shift-II)]

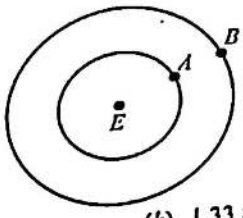
(a) $TA = TB$ (b) $TA > TB$ (if $mA > mB$)

(c) $\frac{T_A}{T_B} = \left(\frac{r_A}{r_B}\right)^{\frac{3}{2}}$ (d) $TA > TB$ (if $rA > rB$)

145. Two satellites A and B of masses 200 kg and 400 kg are revolving round the earth at height of 600 km and 1600 km respectively. If T_A and T_B are the time periods of A and B respectively then the value of $T_B - T_A$

[Given: radius of earth = 6400 km, mass of earth = 6×10^{24} kg]

[25 Feb, 2021 (Shift-I)]



(a) 3.33×10^2s (b) 1.33×10^3s

(c) 4.24×10^2s (d) 4.24×10^2s

146. The distance between two stars of masses $3M_s$ and $6M_s$ is 9 R. If R is the mean distance between the centers of the Earth and Sun, and M_s is the mass of the Sun. The two stars orbit around a common center of mass in circular orbits with period n T, where is the period of Earth's revolution around the Sun. The value is _____. [JEE Adv, 2

147. A satellite is launched into a circular orbit of radius R around while a second satellite is launched into a circular orbit of ra $1.02R$. The percentage difference in the time periods of the satellites is: [20 July, 2021 (Shift-

(a) 0.7 (b) 3.0

(c) 2.0 (d) 1.5

148. Two satellites revolve around a planet in coplanar circular orbi anticlockwise direction. Their period of revolutions are 1 hour 8 hours respectively. The radius of the orbit of nearer satellite is 10^3 km. The angular speed of the farther satellite as observed f the nearer satellite at the instant when both the satellites are clo is $\frac{\pi}{x}$ rad hr^{-1} where x is _____. [1 Sep, 2021 (Shift-

JEE-Advanced

Gravitational Force/Field

Single Correct

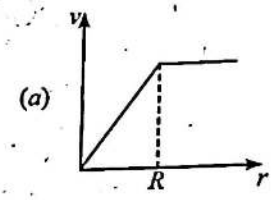
1. Consider a spherical gaseous cloud of mass density $\rho(r)$ in free space where r is the radial distance from its center. The gaseous cloud is made of particles of equal mass m moving in circular orbits about the common center with the same kinetic energy K. The force acting on the particles is their mutual gravitational force.

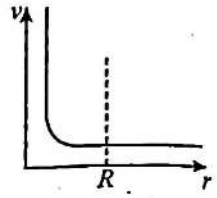
If $\rho(r)$ is constant in time, the particle number density $n(r) = \rho(r)/m$ is C-13 W-28 UA-60 (JEE Adv. 2019)

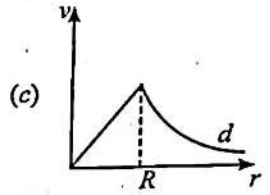
[G is universal gravitational constant]

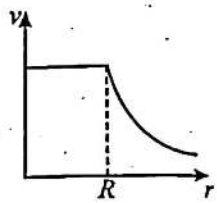
(a) $\frac{K}{6\pi r^2 m^2 G}$ (b) $\frac{K}{\pi r^2 m^2 G}$ (c) $\frac{3K}{\pi r^2 m^2 G}$ (d) $\frac{K}{2\pi r^2 m^2 G}$

2. A spherically symmetric gravitational system of particles has a mass density $\rho = \begin{cases} \rho_0, r < R \\ 0, r > R \end{cases}$, where ρ_0 is a constant. A test mass can undergo circular motion under the influence of the gravitational field of particles. Its speed v as a function of distance r from the centre of the system is represented by (IIT-JEE 2008)

(a) 

(b) 

(c) 

(d) 

3. **Statement-I:** An astronaut in an orbiting space station abov earth experiences weightlessness.

Statement-II: An object moving around the earth unde influence of earth's gravitational force is in a state of 'free-fal (IIT-JEE 2

(a) If Statement-I is true, Statement-II is true; Statement-II i correct explanation for Statement-I

(b) If Statement-I is true, Statement-II is true; Statement-II i a correct explanation for Statement-I

(c) If Statement-I is true; Statement-II is false

(d) If Statement-I is false; Statement-II is true

CLICK_CBSE_KORAJ_EDUTECH

4. A spherical body of radius R consists of a fluid of constant density and is in equilibrium under its own gravity. If $P(r)$ is the pressure at $r(r<R)$, then the correct options is/are **(JEE Adv. 2015)**

(a) $P(r=0)=0$

(b) $\frac{P\left(r=\frac{3R}{4}\right)}{P\left(r=\frac{2R}{3}\right)}=\frac{63}{80}$

(c) $\frac{P\left(r=\frac{3R}{5}\right)}{P\left(r=\frac{2R}{5}\right)}=\frac{16}{21}$

(d) $\frac{P\left(r=\frac{R}{2}\right)}{P\left(r=\frac{R}{3}\right)}=\frac{20}{27}$

5. The magnitudes of the gravitational field at distance r_1 and r_2 from the centre of a uniform sphere of radius R and mass M are F_1 and F_2, respectively. Then **(IIT-JEE 1994)**

(a) $\frac{F_1}{F_2}=\frac{r_1}{r_2}$ if $r_1<R$ and $r_2<R$

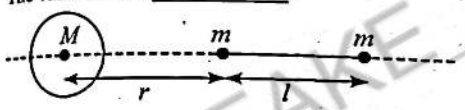
(b) $\frac{F_1}{F_2}=\frac{r_2^2}{r_1^2}$ if $r_1>R>$ and $r_2>R$

(c) $\frac{F_1}{F_2}=\frac{r_1^3}{r_2^3}$ if $r_1<R$ and $r_2<R$

(d) $\frac{F_1}{F_2}=\frac{r_1^2}{r_2^2}$ if $r_1<R$ and $r_2<R$

Numerical Types/Integer Types

6. A large spherical mass M is fixed at one position and two identical masses m are kept on a line passing through the centre of M (see figure). The point masses are connected by a rigid massless rod of length l and this assembly is free to move along the line connecting them. All three masses interact only through their mutual gravitational interaction. When the point mass nearer to M is at a distance $r=3l$ from M the tension in the rod is zero for $m=k\left(\frac{M}{288}\right)$. The value of k is _____.



(JEE Adv. 2015)

Subjective

7. Distance between the centres of two stars is $10a$. The masses of these stars are M and $16M$ and their radii a and $2a$ respectively. A body of mass m is fired straight from the surface of the larger star towards the surface of the smaller star. What should be its minimum initial speed to reach the surface of the smaller star? Obtain the expression in terms of G, M and a. **(IIT-JEE 1996)**

8. Three particles, each of mass m, are situated at the vertices of an equilateral triangle of side length a. The only forces acting on the particles are their mutual gravitational forces. It is desired that each particle moves in a circle while maintaining the original mutual separation a. Find the initial velocity that should be given to each particle and also the time period of the circular motion. **(IIT-JEE 1988)**

Variation of g

Single Correct

9. A planet of radius $R=\frac{1}{10}\times$ (radius of earth) has the same mass density as earth. Scientists dig a well of depth $\frac{R}{5}$ on it and lower a wire of the same length and of linear mass density $=10^{-3}$ kg m^{-1} into it. If the wire is not touching anywhere, the force applied at the top of the wire by a person holding it in place is (take the radius of earth $=6\times10^6$ m and the acceleration due to gravity of earth is 10 ms^{-2}) **C-14.06 W-32.44 UA-53.51 (JEE Adv. 2014)**

(a) 96 N (b) 108 N (c) 120 N (d) 150 N

10. A simple pendulum has a time period T_1 when on the earth's surface and T_2 when taken to a height R above the earth's surface, where R is the radius of the earth. The value of T_2/T_1 is **(JEE Adv. 2001)**

(a) 1 (b) $\sqrt{2}$ (c) 4 (d) 2

11. If the radius of the earth were to shrink by one per cent, its mass remaining the same, the acceleration due to gravity on the earth's surface would **(IIT-JEE 1981)**

(a) decrease (b) remain unchanged

(c) increase (d) be zero

Numerical Types/Integer Types

12. Two spherical stars A and B have densities ρ_A and ρ_B, respectively. A and B have the same radius, and their masses M_A and M_B are related by $M_B=2M_A$. Due to an interaction process, star A loses some of its mass, so that its radius is halved, while its spherical shape is retained, and its density remains ρ_A. If v_A and v_B are the escape velocities from A and B after interaction process, the ratio $\frac{v_B}{v_A}=\sqrt{\frac{10n}{15^{1/3}}}$. The value of n is _____.

C-3.50,W-56.19,UA-40.31 (JEE Adv. 2022)

Fill in the Blanks

13. The numerical value of the angular velocity of rotation of the earth should be _____ rad/s in order to make the effective acceleration due to gravity at equator equal to zero. **(IIT-JEE 1984)**

"Gravitation Potential, Potential Energy and Escape Velocity"

Single Correct

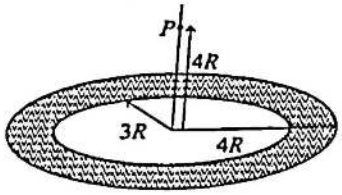
14. A rocket is launched normal to the surface of the Earth, away from the Sun, along the line joining the Sun and the Earth. The Sun is 3×10^5 times heavier than the Earth and is at a distance 2.5×10^4 times larger than the radius of Earth. The escape velocity from Earth's gravitational field is $v_e=11.2$ kms^{-1}. The minimum initial velocity (v_s) required for the rocket to be able to leave the Sun-Earth system is closest to (Ignore the rotation and revolution of the Earth and the presence of any other planet) **C-30.11 W-26.28 UA-43.61 (JEE Adv. 2017)**

(a) $v_s=72$ km s^{-1} (b) $v_s=22$ km s^{-1}

(c) $v_s=42$ km s^{-1} (d) $v_s=62$ km s^{-1}

@FAKE_OBEX_@_TELEGRAM

15. A thin uniform annular disc (see figure) of mass M has outer radius $4R$ and inner radius $3R$. The work required to take a unit mass from point P on its axis to infinity is **(IIT-JEE 2010)**



(a) $\frac{2GM}{7R}\left(4\sqrt{2}-5\right)$ (b) $-\frac{2GM}{7R}\left(4\sqrt{2}-5\right)$

(c) $\frac{GM}{4R}$ (d) $\frac{2GM}{5R}\left(\sqrt{2}-1\right)$

16. If g is the acceleration due to gravity on the earth's surface, the gain in the potential energy of an object of mass m raised from the surface of the earth to a height equal to the radius R of the Earth, is **(IIT-JEE 1983)**

(a) $\frac{1}{2}mgR$ (b) $2\,mgR$

(c) mgR (d) $\frac{1}{4}mgR$

Multiple Correct

17. Two bodies, each of mass M, are kept fixed with a separation $2L$. A particle of mass m is projected from the mid-point of the line joining their centres, perpendicular to the line. The gravitational constant is G. The correct statement(s) is/are **C-37.51 W-32.57 UA-29.92 (JEE Adv. 2013)**

(a) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $4\sqrt{\frac{GM}{L}}$

(b) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $2\sqrt{\frac{GM}{L}}$

(c) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $\sqrt{\frac{2GM}{L}}$

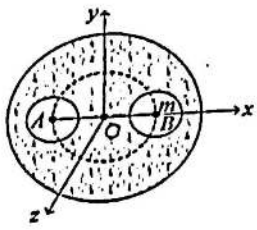
(d) The energy of the mass m remains constant

18. Two spherical planets P and Q have the same uniform density ρ, masses M_P and M_Q, and surface areas A and $4A$, respectively. A spherical planet R also has uniform density ρ and its mass is $(M_P + M_Q)$. The escape velocities from the planets P, Q and R, are v_P, v_Q and v_R, respectively. Then, **(IIT-JEE 2012)**

(a) $v_Q > v_R > v_P$ (b) $v_R > v_Q > v_P$

(c) $v_R / v_P = 3$ (d) $v_P / v_Q = 1/2$

19. A solid sphere of uniform density and radius 4 units is located with its centre at the origin O of coordinates. Two spheres of equal radii 1 unit, with their centres at $A(-2, 0, 0)$ and $B(2, 0, 0)$ respectively, are taken out of the solid leaving behind spherical cavities as shown in figure. **(IIT-JEE 1993)**



Then,

(a) the gravitational field due to this object at the origin is zero

(b) the gravitational field at the point $B(2, 0, 0)$ is zero

(c) the gravitational potential is the same at all points of circle $y^2 + z^2 = 36$

(d) the gravitational potential is the same at all points on the circle $y^2 + z^2 = 4$

Numerical Types/Integer Types

20. A bullet is fired vertically upwards with velocity v from the surface of a spherical planet. When it reaches its maximum height, its acceleration due to the planet's gravity is $\frac{1}{4}$ th of its value at the surface of the planet. If the escape velocity from the planet is $v_{esc} = v\sqrt{N}$, then the value of N is (ignore energy loss due to atmosphere) **(JEE Adv. 2015)**

21. Gravitational acceleration on the surface of a planet is $\frac{\sqrt{6}}{11}g$, where g is the gravitational acceleration on the surface of the earth. The average mass density of the planet is 2/3 times that of the earth. If the escape speed on the surface of the earth is taken to be 11 kms^{-1}, the escape speed on the surface of the planet in kms^{-1} will be **(IIT-JEE 2010)**

22. There is a crater of depth $\frac{R}{100}$ on the surface of the moon (radius R). A projectile is fired vertically upward from the crater with velocity which is equal to the escape velocity v from the surface of the moon. Find the maximum height attained by the projectile. **(IIT-JEE 2003)**

Fill in the Blanks

23. A particle is projected vertically upwards from the surface of Earth (radius) with a kinetic energy equal to half of the minimum value needed for it to escape. The height to which it rises above the surface of Earth is..... **(IIT-JEE 1993)**

24. The masses and radii of the Earth and the Moon are M_1, R_1, and M_2, R_2 respectively. Their centres are a distance d apart. The minimum speed with which a particle of mass m should be projected from a point midway between the two centres so as to escape to infinity is ..... . **(IIT-JEE 1983)**

@FAKE_CBSE_X@RAJ_BHUNET

Satellite Motion

Single Correct

25. Two satellites P and Q are moving in different circular orbits around the Earth (radius R). The heights of P and Q from the Earth surface are h_P and h_Q, respectively, where $h_P = R/3$. The accelerations of P and Q due to Earth's gravity are g_P and g_Q, respectively. If $g_P/g_Q = 36/25$, what is the value of h_Q?
C-53.9 W-22.85 UA-23.25 (JEE Adv. 2023)
(a) $3R/5$ (b) $R/6$ (c) $6R/5$ (d) $5R/6$

26. A geostationary satellite orbits around the earth in a circular orbit of radius 36,000 km. Then, the time period of a spy satellite orbiting a few hundred km above the earth's surface (R_e = 6400 km) will approximately be (IIT-JEE 2002)
(a) 1/2 h (b) 1 h (c) 2 h (d) 4 h

27. A satellite S is moving in an elliptical orbit around the earth. The mass of the satellite is very small compared to the mass of the earth (IIT-JEE 1998)
(a) The acceleration of S is always directed towards the centre of the earth
(b) The angular momentum of S about the centre of the earth changes in direction, but its magnitude remains constant
(c) The total mechanical energy of S varies periodically with time
(d) The linear momentum of S remains constant in magnitude

28. Imagine a light planet revolving around a very massive star in a circular orbit of radius R with a period of revolution T. If the gravitational force of attraction between the planet and the star is proportional to $R^{-5/2}$, then (IIT-JEE 1989)
(a) T^2 is proportional to R^2 (b) T^2 is proportional to $R^{7/2}$
(c) T^2 is proportional to $R^{3/2}$ (d) T^2 is proportional to $R^{3.75}$

Match the Column

29. A planet of mass M, has two natural satellites with masses m_1 and m_2. The radii of their circular orbits are R_1 and R_2, respectively. Ignore the gravitational force between the satellites. Define v_1, L_1, K_1 and T_1 to be respectively, the orbital speed, angular momentum, kinetic energy and time period of revolution of satellite 1; and v_2, L_2, K_2 and T_2 to be the corresponding quantities of satellite 2. Given, $m_1/m_2 = 2$ and $R_1/R_2 = 1/4$, match the ratios in List-I to the numbers in List-II. (JEE Adv. 2018)

List-I	List-II
P. v_1/v_2	1. 1/8
Q. L_1/L_2	2. 1
R. K_1/K_2	3. 2
S. T_1/T_2	4. 8

(a) $P \to 4; Q \to 2; R \to 1; S \to 3$
(b) $P \to 3; Q \to 2; R \to 4; S \to 1$
(c) $P \to 2; Q \to 3; R \to 1; S \to 4$
(d) $P \to 2; Q \to 3; R \to 4; S \to 1$

Fill in the Blanks

30. A geostationary satellite is orbiting the earth at a height of $6R$ above the surface of the earth where R is the radius of earth. The time period of another satellite at a height of 2.5 R from the surface of the earth is _____ hours. (IIT-JEE 1987)

True/False

31. It is possible to put an artificial satellite into orbit in such a way that it will always remain directly over New Delhi. (IIT-JEE 1984)

Subjective

32. Two satellites S_1 and S_2 revolve round a planet in coplanar circular orbits in the same sense. Their periods of revolution are 1 h and 8 h, respectively. The radius of the orbit of S_1 is 10^4 km when S_2 is closest to S_1. Find (IIT-JEE 1986)
(a) the speed of S_2 relative to S_1,
(b) the angular speed of S_2 as actually observed by an astronaut in S_1.

33. An artificial satellite is moving in a circular orbit around the Earth with a speed equal to half the magnitude of escape velocity from the Earth. (IIT-JEE 1990)
(a) Determine the height of the satellite above the earth's surface.
(b) If the satellite is stopped suddenly in its orbit and allowed to fall freely onto the Earth, find the speed with which it hits the surface of the Earth.

Kepler's Laws

Single Correct

34. A double star system consists of two stars A and B which have time periods T_A and T_B. Radius R_A and R_B and mass M_A and M_B. Choose the correct option. (IIT-JEE 2006)
(a) If $T_A > T_B$ then $R_A > R_B$ (b) If $T_A > T_B$ then $M_A > M_B$
(c) $\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{R_A}{R_B}\right)^3$ (d) $T_A = T_B$

35. If the distance between the earth and the sun were half its present value, the number of days in a year would have been (IIT-JEE 1996)
(a) 64.5 (b) 129
(c) 182.5 (d) 730

Numerical Types/Integer Types

36. The distance between two stars of masses $3M_s$ and $6M_s$ is 9 R. Here R is the mean distance between the centers of the Earth and the Sun, and M_s is the mass of the Sun. The two stars orbit around their common center of mass in circular orbits with period n T, where T is the period of Earth's revolution around the Sun. The value of n is _____. C-16.22 W-70.06 UA-13.72 (JEE Adv. 2021)

Fill in the Blanks

37. According to Kepler's second law, the radius vector to a planet from the sun sweeps out equal areas in equal intervals of time. This law is a consequence of the conservation of _____. (IIT-JEE 1985)

@RAJ_EDUNET

ANSWER KEY

JEE-Main

1. (b)	2. (d)	3. (c)	4. (d)	5. (c)	6. (b)	7. (a)	8. (a)	9. (b)	10. (c)
11. (c)	12. (c)	13. (d)	14. (d)	15. (c)	16. (b)	17. (d)	18. (d)	19. (d)	20. (d)
21. [8]	22. (b)	23. (d)	24. (d)	25. (d)	26. (c)	27. (c)	28. (d)	29. (b)	30. (d)
31. (b)	32. (c)	33. (b)	34. (c)	35. (a)	36. (c)	37. (d)	38. (c)	39. (b)	40. (d)
41. (d)	42. (d)	43. (a)	44. (c)	45. (b)	46. (d)	47. (a)	48. (a)	49. [2]	50. (d)
51. (c)	52. (b)	53. (b)	54. (d)	55. (a)	56. [4]	57. (c)	58. (a)	59. (a)	60. (a)
61. (d)	62. (a)	63. (a)	64. (d)	65. (a)	66. (b)	67. (a)	68. (b)	69. (a)	70. (a)
71. (b)	72. (a)	73. (c)	74. (d)	75. (d)	76. (c)	77. (b)	78. (b)	79. (b)	80. (a)
81. (a)	82. (b)	83. (a)	84. [2.3]	85. (b)	86. (b)	87. (a)	88. (b)	89. (b)	90. [64]
91. [10]	92. [2]	93. [3]	94. (a)	95. (c)	96. (a)	97. (d)	98. (d)	99. [16]	100. (d)
101. (b)	102. (c)	103. (d)	104. (c)	105. (d)	106. (b)	107. (d)	108. (c)	109. (d)	110. (d)
111. (b)	112. (c)	113. (a)	114. [2]	115. [4]	116. (b)	117. (a)	118. (c)	119. (a)	120. (b)
121. (b)	122. (d)	123. (b)	124. (b)	125. (b)	126. (b)	127. [25]	128. (b)	129. (a)	130. (c)
131. (d)	132. (a)	133. (d)	134. (c)	135. (b)	136. (c)	137. (a)	138. (c)	139. (d)	140. (b)
141. (c)	142. (b)	143. (d)	144. (a)	145. (b)	146. [9]	147. (b)	148. [3]		

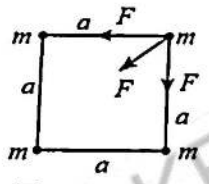
JEE-Advanced

1. (d)	2. (c)	3. (a)	4. (b, c)	5. (a, b)	6. [7]	9. (b)	10. (d)	11. (c)	12. [2.3]
14. (c)	15. (a)	16. (a)	17. (b,d)	18. (b,d)	19. (a, c, d)	20. [2]	21. [3]	22. [99R]	25. (a)
26. (c)	27. (a)	28. (b)	29. (b)	31. [False]	34. (d)	35. (b)	36. [9]		

EXPLANATIONS

JEE-Main

1. (b)



$F_{net} = \sqrt{2}F + F'$

$F = \frac{Gm^2}{a^2}, F' = \frac{Gm^2}{(\sqrt{2}a)^2}$

$F_{net} = \sqrt{2}\frac{Gm^2}{a^2} + \frac{Gm^2}{2a^2}$

$\left(\frac{2\sqrt{2}+1}{32}\right)\frac{Gm^2}{L^2} = \frac{Gm^2}{a^2}\left(\frac{2\sqrt{2}+1}{2}\right)$

$a = 4L$

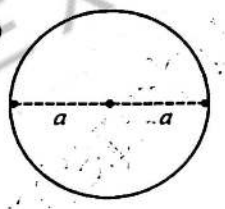
2. (d) According to question, $R = \frac{L}{\pi}$

Field at center

$E = \frac{2G\frac{M}{L}}{R} = \frac{2GM\pi}{L^2}$

$\therefore F_m = mE = \frac{2GM\pi m}{L^2}$

3. (c)



Gravitational force of attraction

= centripetal force

$\therefore F_g = m\omega^2 r$

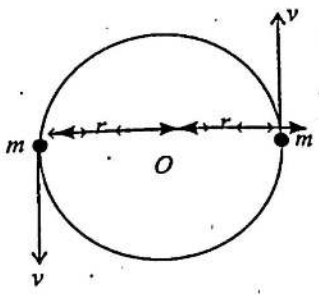
$\Rightarrow \frac{Gmm}{(2a)^2} = m\omega^2 a$

$\omega = \sqrt{\frac{Gm}{4a^3}}$

4. (d) As the particles are moving in a circular path,

$\frac{Gm^2}{(2r)^2} = \frac{mv^2}{r}$

$\Rightarrow \frac{Gm^2}{4r^2} = \frac{mv^2}{r}$



$v = \sqrt{\frac{Gm}{4r}}$

5. (c) Initially, $F = \frac{Gm^2}{r^2}$

When one-third mass of one object transferred to the other, then now force

$F' = \frac{G \times \left(\frac{2m}{3}\right)\left(\frac{4m}{3}\right)}{r^2} = \frac{8}{9}\frac{Gm^2}{r^2}$

On dividing equation (i) with equation (ii)

$\frac{F}{F'} = \frac{9}{8} \Rightarrow F' = \frac{8}{9}F$

@FAKE_CBSE_GURUJI_EDUNET

6. (b) Net force on A, B and C.

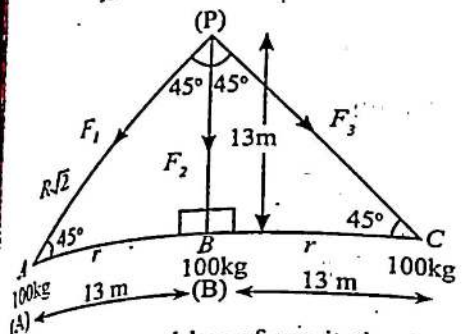
$F_{net} = F_1\cos45° + F_2 + F_3\cos45°$

$= \frac{GMM}{(\sqrt{2})^2}\times\frac{1}{\sqrt{2}} + \frac{GMM}{r^2} + \frac{GMM}{(r\sqrt{2})^2}\times\frac{1}{\sqrt{2}}$

$= \frac{GMM}{r^2} + \sqrt{2}\frac{GMM}{(\sqrt{2}r)^2}$

$= \frac{GMM}{r^2}\left(1+\frac{1}{\sqrt{2}}\right)$

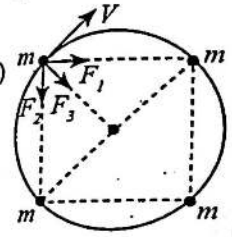
$= \frac{G\times10^4}{13^2}\left(1+\frac{1}{\sqrt{2}}\right) \approx 100\ G$



7. (a) Universal law of gravitation holds good for any pair of bodies in the universe. This is correct statement.

At the centre of the earth gravitational acceleration is zero. Therefore, the weight of any person becomes zero when the person is at the centre of the Earth. i.e., Weight = mg = 0

8. (a)



From the above diagram, net force on mass m.

$F_1\cos45° + F_2\cos45° + F_3 = \frac{mv^2}{r}$

$\Rightarrow \frac{Gm^2}{(\sqrt{2}r)^2}\cdot\frac{1}{\sqrt{2}} + \frac{Gm^2}{(\sqrt{2}r)^2}\cdot\frac{1}{\sqrt{2}} + \frac{Gm^2}{(2r)^2} = \frac{mv^2}{r}$

$\Rightarrow v^2 = \frac{Gm}{r}\left(\frac{1}{2\sqrt{2}} + \frac{1}{2\sqrt{2}} + \frac{1}{4}\right)$

$\Rightarrow v = \sqrt{\frac{Gm}{4r}\left(2\sqrt{2}+1\right)}$ ...(i)

On putting $m = 1$ kg and $r = 1$ m, in equation (i)

$v = \frac{1}{2}\sqrt{G\left(1+2\sqrt{2}\right)}$

9. (b) $F_1 = \frac{GMm}{(3R)^2} = \frac{GMm}{9R^2}$ ...(i)

$F_2 = \frac{GMm}{(3R)^2} - \frac{G\frac{M}{8}m}{\left(\frac{5R}{2}\right)^2} = \frac{GMm}{R^2}\left(\frac{1}{9}-\frac{1}{50}\right)$

$= \frac{GMm}{9R^2}\left(1-\frac{9}{5}\right)$

$F_2 = F_1\left(1-\frac{9}{5}\right)$ (Using (i))

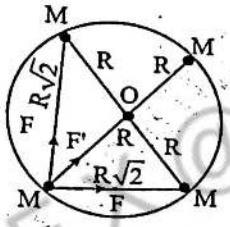
$\frac{F_1}{F_2} = \frac{1}{1-\frac{9}{50}} = \frac{50}{41}$

10. (c)

$F = M_{sphere}E_{ring} = M\times\frac{Gm\times\sqrt{8}R}{\left(R^2+8R^2\right)^{3/2}}$

$= \frac{\sqrt{8}GMm}{27R^2}$

11. (c) $F_{net} = \frac{Mv^2}{R}$ [$\because$ for circular motion]



$\sqrt{2}F + F' = \frac{Mv^2}{R}$

$\sqrt{2}\frac{GMM}{(\sqrt{2}R)^2} + \frac{GMM}{(2R)^2} = \frac{Mv^2}{R}$

$\frac{GM}{R}\left[\frac{1}{\sqrt{2}}+\frac{1}{4}\right] = v^2,\ v = \sqrt{\frac{GM(4+\sqrt{2})}{R4\sqrt{2}}}$

$v = \frac{1}{2}\sqrt{\frac{GM}{R}(2\sqrt{2}+1)}$

12. (c) $\rho(r) = \rho_0\left(1-\frac{r^2}{R^2}\right)$

$\frac{dm}{dV} = \rho_0\left(1-\frac{r^2}{R^2}\right)$

$dm = \rho_0\left(1-\frac{r^2}{R^2}\right)dV$

$\therefore m = \int_0^r \rho_0\left(1-\frac{r^2}{R^2}\right)\times4\pi r^2 dr$

$= 4\pi\rho_0\left(\frac{r^3}{3}-\frac{r^5}{5R^2}\right)$

$\therefore E = \frac{Gm}{r^2} = \frac{G4\pi\rho_0}{r^2}\left[\frac{r^3}{3}-\frac{r^5}{5R^2}\right]$

$= G4\pi\rho_0\left[\frac{r}{3}-\frac{r^3}{5R^2}\right]$

$\therefore \frac{dE}{dr} = 0 \Rightarrow r = \sqrt{\frac{5}{9}}R$

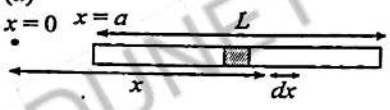
13. (d) $3 = \frac{Gm_2}{2^2}$

$2 = \frac{Gm_1}{1^2}$

$\therefore \frac{3}{2} = \frac{1}{4}\frac{m_2}{m_1}$

$\frac{m_1}{m_2} = \frac{1}{6}$

14. (d)



Mass of element = $dm = (A + Bx^2)dx$

Field due to element at $x = 0$

$dE = \frac{G(dm)}{x^2} = \left(\frac{GA}{x^2}+GB\right)dx$

Total field

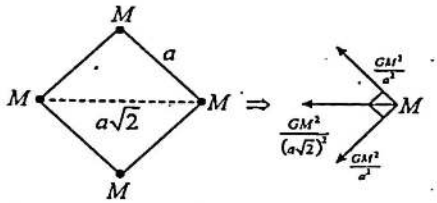
$E = GA\int_a^{a+L}\frac{1}{x^2}dx + GB\int_a^{a+L}dx$

$= G\left[A\left(\frac{1}{a}-\frac{1}{a+L}\right)+BL\right]$

So, force = mE

$= Gm\left[A\left(\frac{1}{a}-\frac{1}{a+L}\right)+BL\right]$

15. (c)



Net force on particle towards centre of circle is

$F_c = \frac{GM^2}{2a^2} + \frac{GM^2}{a^2}\sqrt{2}$

$= \frac{GM^2}{a^2}\left(\frac{1}{2}+\sqrt{2}\right)$

This force will act as centripetal force. Distance of particle from centre of circle is $\frac{a}{\sqrt{2}}$.

@FAKE_CBSE_K@RAJ_EDUNET

$$r=\frac{a}{\sqrt{2}}, F_c=\frac{mv^2}{r}$$

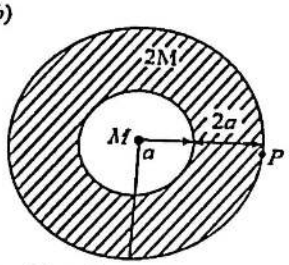
$$\frac{mv^2}{a/\sqrt{2}}=\frac{GM^2}{a^2}\left(\frac{1}{2}+\sqrt{2}\right)$$

$$v^2=\frac{GM}{a}\left(\frac{1}{2\sqrt{2}}+1\right)$$

$$v^2=\frac{GM}{a}(1.35)$$

$$v=1.16\sqrt{\frac{GM}{a}}$$

16. (b)



Using, Gauss's Law for gravitation

$g\cdot 4\pi r2$ = (Mass enclosed) $4\pi G$

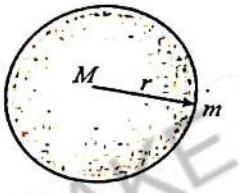
$$g=\frac{3M4\pi G}{4\pi(3a)^2}=\frac{MG}{3a^2}$$

17. (d) Let total mass included in a sphere of radius r be M.

For a particle of mass M,

$$\frac{GMm}{r^2}=\frac{mv^2}{r}$$

$$\Rightarrow \frac{GMm}{r}=2K$$



$$\therefore \Rightarrow M=\frac{2Kr}{GM}$$

$$\therefore dM=\frac{2Kdr}{GM}$$

$$\Rightarrow (4\pi r^2dr)\rho=\frac{2Kdr}{GM}$$

$$\Rightarrow \rho=\frac{K}{2\pi r^2GM}$$

$$\therefore n=\frac{\rho}{m}=\frac{K}{2\pi r^2m^2G}$$

18. (d) $m=\int_0^R \rho 4\pi r^2dr$

$m=4\pi KR$; $v\propto\sqrt{4\pi K}$

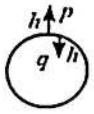
$$\frac{T}{R}=\frac{2\pi}{\sqrt{4\pi K}}=\text{constant}$$

19. (d) Acceleration due to gravity at point p above the surface of earth

$$g_p=\frac{gR^2}{(R+h)^2}$$

Acceleration due to gravity at point q below the surface of earth

$$g_q=g\left(1-\frac{h}{R}\right)$$



$$g_p=g_q$$

$$\frac{g}{\left(1+\frac{h}{R}\right)^2}=g\left(1-\frac{h}{R}\right)$$

$$\left(1-\frac{h^2}{R^2}\right)\left(1+\frac{h}{R}\right)=1$$

Take $\frac{h}{R}=x$

So

$$x^3-x+x^2=0$$

$$x=\frac{\sqrt{5}-1}{2}$$

$$h=\frac{R}{2}\left(\sqrt{5}-1\right)$$

20. (d) As $g=\frac{GM}{R^2}\Rightarrow\frac{g_2}{g_1}=\frac{R_1^2}{R_2^2}$

$$\therefore g_2=4g_1\left(R_2=\frac{R_1}{2}\right)$$

21. [8] the length of the string = 4m

Acceleration due to gravity $g'=\frac{g}{4}$

the time period of small oscillations

$$T=2\pi\sqrt{\frac{4\ell}{g}}$$

$$T=2\pi\sqrt{\frac{4\times4}{g}}$$

$$T=2\pi\frac{4}{\pi}=8s$$

22. (b) $g'=\frac{GMe}{(3R)^2}=\frac{1}{9}g$

$$T=2\pi\sqrt{\frac{\ell}{g'}}$$

For second pendulum,

$T=2$ sec

$$2=2\pi\sqrt{\frac{\ell}{g}9}\ ,\ \ell=\frac{1}{9}\text{m}$$

23. (d) Since, mg = 300N

$$\therefore m=\frac{300}{g}$$

Acceleration due to gravity at depth

$$g_d=g\left[1-\frac{d}{R}\right]$$

$$g_d=g\left[1-\frac{R}{4R}\right]\qquad\left(\because d=\frac{R}{4}\right)$$

$$g_d=\frac{3g}{4}$$

Weight at depth $=m\times\frac{3g}{4}$

$$=\frac{3}{4}\times300=225$$

24. (d) Value of $g'=\frac{g}{\left(1+\frac{h}{R}\right)^2}$

$$=\frac{g}{(1+2)}=\frac{g}{9}$$

g = gravitational acceleration at surface of earth

Force $=mg=90\times\frac{g}{9}=100N$

25. (d) Gravity at depth d $\left(=\frac{R}{2}\right)$

$$g'=g\left(1-\frac{R/2}{R}\right)=\frac{g}{2}=5m/s^2$$

Weight at depth R/2 $=\frac{200}{10}\times5=100$

26. (c) Effective acceleration due to gravity due to rotation of earth $g_{eff}=g-\omega^2R_e\sin^2\theta$ where, θ is co-latitude angle

$g_{eff}=g\left(1-\frac{d}{R_e}\right)$ here d is depth

27. (c) Formula of acceleration due to gravity

$$g=\frac{GM}{R^2}$$

$$\because M=\rho V=\rho\times\frac{4}{3}\pi R^3$$

$$g=\frac{G}{R^2}\times\rho\times\frac{4\pi}{3}R^3=\left(\frac{4\pi}{3}G\right)\rho R$$

$$\therefore g=\frac{g_A}{g_B}=\frac{R\times\rho}{4R\times\frac{\rho}{3}}=\frac{3}{4}$$

28. (d) Acceleration due to gravity at a height h above the surface of earth,

$$g'=\frac{g}{\left[1+\frac{h}{R}\right]^2}$$

So, weight of the body at given height

$$mg'=\frac{mg}{\left[1+\frac{h}{R}\right]^2}=\frac{18}{\left[1+\frac{1}{2}\right]^2}=8N.$$

@AKE_CBSE_X_@RAJEEDUNET

29. (b) At the surface of earth time period, $T=2\pi\sqrt{\frac{\ell}{g}}$

At a height h above the surface of earth $=R$

$$g'=\frac{g}{\left(1+\frac{h}{R}\right)^2}=\frac{g}{4}$$

$$\Rightarrow xT=2\pi\sqrt{\frac{\ell}{(g/4)}}$$

$$\Rightarrow xT=2T$$

$$\Rightarrow x=2$$

30. (d) Gravity at depth

$$g'=g\left(1-\frac{d}{R}\right)=g\left(1-\frac{R}{2R}\right)=\frac{g}{2}$$

So weight, $W'=mg'=\frac{mg}{2}=200N$

$\{\because mg=400N\}$

31. (b) Due to rotation, gravity $g' = g - r\omega^2\cos^2\lambda$.

At pole $g' = g$ $(\because\lambda=90°)$

At equator $g' = g_s - r\omega^2\cos^2\lambda = g_s - r\omega^2$

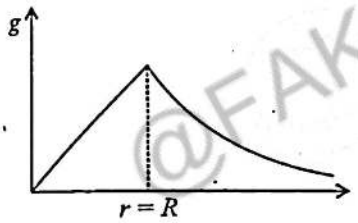
Effect is maximum at equator.

32. (c) Acceleration due to gravity at height h above the surface of earth.

$$g'=\frac{g}{\left(1+\frac{h}{R}\right)^2}$$

Acceleration due to gravity at a depth d below the surface of earth.

$$g'=g\left\{1-\frac{d}{R}\right\}$$



33. (b) We know that, if g_0 be the value of gravity constant at the surface of earth, then value of gravity constant at distance r from surface of earth is,

$$g'=\frac{g_0}{\left(\frac{r}{R}\right)^2}=\frac{g_0}{10^2} \qquad [\because r=10R]$$

$$=\frac{g_0}{100},\ \Rightarrow W'=\frac{W}{100}$$

34. (c) We know thas mass

$$m=\rho\times\frac{4}{3}\pi R^3$$

$$\therefore R\propto m^{\frac{1}{3}} \qquad (\because \text{Density is equal})$$

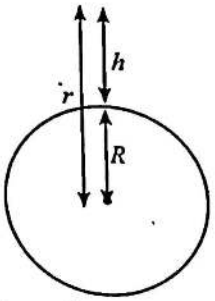
Weight $= W \propto g \propto \frac{m}{R^2}$

$$\therefore W\propto\frac{m}{m^{2/3}}\propto m^{1/3}$$

$$\frac{W}{W_1}=\left(\frac{m}{2m}\right)^{1/3}=\left(\frac{1}{2}\right)^{1/3}$$

So, $W_1 = 2^{1/3}W$

35. (a) Gravity at the surface of earth $r = R + h$ and $g=\frac{GM}{R^2}$



r = distance from center of earth

$$\Rightarrow g'=\frac{GM}{r^2}=\frac{GM}{(R+h)^2}\Rightarrow g'=\frac{GM}{R^2\left(1+\frac{h}{R}\right)^2}$$

$$\Rightarrow g'(h)=\frac{GM}{R^2}\left(1+\frac{h}{R}\right)^{-2}$$

Using binominal expanssion

$$\Rightarrow g'=\frac{GM}{R^2}\left(1-\frac{2h}{R}\right)$$

$$\Rightarrow g'=g\left(1-\frac{2h}{R}\right)$$

36. (c) Acceleration due to gravity

$$g=\frac{GM}{R^2}=\frac{4}{3}\pi G\rho R$$

$$\left(\because M=\rho\times\frac{4}{3}\pi R^3\right)$$

$$\therefore\frac{g_2}{g_1}=\frac{\rho_2}{\rho_1}\times\frac{R_2}{R_1}=\frac{1}{2}\times1.5=\frac{3}{4}$$

37. (d) $g\left(1-\frac{d}{R}\right)=4\times\frac{g}{\left(1+\frac{3R}{R}\right)^2}$

$$\Rightarrow 1-\frac{d}{R}=\frac{1}{4}\Rightarrow d=4800\text{ km}$$

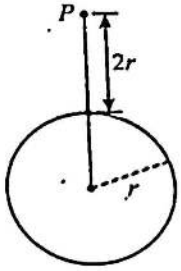
38. (c) $\because T\propto\frac{1}{\sqrt{g}}$

As g decreases T will increase making the clock slow.

39. (b) $\Rightarrow g'=\frac{gR^2}{\left(R+\frac{R}{4}\right)^2}=\frac{16g}{25}$

$\therefore$ Weight $= Mg' = \frac{16}{25}\times100 = 64N$

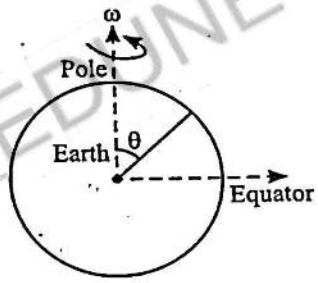
40. (d)



$$g=\frac{GM}{r^2}$$

Now, $g'=\frac{GM}{(3r)^2}=\frac{g}{9}$

41. (d) Effective acceleration due to rotation of earth,



$g' = g - \omega^2 R\sin\theta$

At pole, $\theta = 0$

$\therefore g' = g$

At equator, $\theta = 90°$

$g' = g - \omega^2 R$

g decreases as we move from pole to equator

Therefore is false statement

But 'R' Statement-Is true

42. (d) $g=\frac{GM}{r^2}$

$$dg=-2\frac{GM}{r^3}dr$$

$$\Rightarrow dg=-2\left(\frac{GM}{r^2}\right)\frac{dr}{r}$$

$$\Rightarrow\frac{dg}{g}\times100=-2\left(\frac{dr}{r}\times100\right)$$

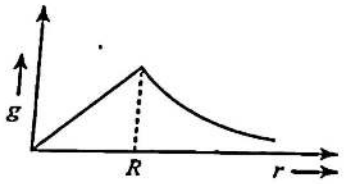
$$=-2\times(-2\%)=4\%$$

Hence, acceleration due to gravity will increase by 4%

43. (a) $g\propto r \quad 0\le r\le R$

$$g\propto\frac{1}{r^2} \quad r>R$$

@FAKE_CBSE_K@RAJ_EDUNET



44. (c) $\because t \propto \frac{1}{\sqrt{g}} \Rightarrow \frac{t_1}{t_2} = \frac{4}{6} = \sqrt{\frac{g_2}{g_1}}$

and, $\frac{g_2}{g_1} = \frac{g_0}{g_0\left(1+\frac{h}{R}\right)^2}$

$\Rightarrow \left(1+\frac{h}{R}\right)^2 = \frac{6}{4}$

$\Rightarrow 1+\frac{h}{R} = \frac{3}{2} \Rightarrow h = \frac{R}{2} = 3200\text{km}$

45. (b) As mass 'M' remains same

$\Rightarrow g' = \frac{g}{3}$

Now, $g' = g\left(\frac{R}{R+h}\right)^2$

$\Rightarrow \frac{g}{3} = g\left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{R}{R+h} = \frac{1}{\sqrt{3}}$

$\Rightarrow h = 4685$ km

46. (d) Time period of second pendulum, $T = 2$ s

Gravitational acceleration at a height h from the surface of earth,

$$g' = g\left(\frac{R}{R+h}\right)^2 = g\left(\frac{R}{R+2R}\right)^2 = \frac{g}{9}$$

Time period,

$$T = 2\pi\sqrt{\frac{\ell}{g'}} \Rightarrow \ell = \frac{g'T^2}{4\pi^2}$$

$$= \frac{\frac{g}{9}\times(2)^2}{4\pi^2} = \frac{1}{9}\text{m}$$

47. (a) Since, $g = \frac{GM}{R^2}$

$$g' = g\left(\frac{R}{\frac{5}{4}R}\right)^2 = \frac{16g}{25}$$

$$\% \text{ Change} = \frac{g'-g}{g}\times 100$$

$$= \frac{\frac{16}{25}g - g}{g}\times 100$$

$$= -36\%$$

(a) $g' = g\frac{R^2}{(R+h)^2} = \frac{gR^2}{R^2\left(1+\frac{h}{R}\right)^2}$

When, $h << R$

$$g' = g\left(1-\frac{2h}{R}\right) = g\left(1-2\times\frac{32}{6400}\right)$$

$$g' = \frac{99g}{100} = 0.99g$$

Percentage decrease in weight

$$= \frac{g-g'}{g}\times 100 = 1\%$$

49. [2] Given, $g_h = g\alpha_h$, $h << R$

$$\Rightarrow g\left(1-\frac{2h}{R}\right) = g\left(1-\frac{\alpha h}{R}\right)$$

$$\Rightarrow \frac{2h}{R} = \alpha\frac{h}{R} \Rightarrow \alpha = 2$$

50. (d) According to the question, bodies at equator start floating.

$\therefore g_e = g - \omega^2 R \Rightarrow 0 = g - \omega^2 R \Rightarrow \omega = \sqrt{\frac{g}{R}}$

$\Rightarrow T$

$$= \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{R}{g}} = 2\times 3.14\times\sqrt{\frac{6400\times10^3}{10}}$$

≈ 84 min.

51. (c) Acceleration due to gravity at r height is $= \frac{g}{\left(1+\frac{r}{R}\right)^2}$

Acceleration due to gravity at r depth is

$$= \frac{g}{\left(1-\frac{r}{R}\right)}$$

So, required ratio sss

$$= \frac{g_{depth}}{g_{height}} = 1+\frac{r}{R}-\frac{r^2}{R^2}-\frac{r^3}{R^3}$$

52. (b) Layers of atmosphere are in order of (from bottom) troposphere, stratosphere, mesosphere, thermosphere.

53. (b) Acceleration due to gravity decreases as we go from pole to equator. Therefore, weight of the body will also reduces. Hence, weight on equator will be slightly smaller than 49 N.

54. (d) $g = \frac{4}{3}\pi R\rho G$ ... (i)

(ρ = density)

Now $\Rightarrow M = \rho v = \rho\times\frac{4}{3}\pi R^3$

Since density of both planet is same therefore,

$M \propto R^3$

$$\therefore \frac{M_P}{M_E} = \frac{R_P^3}{R_E^3}$$

$$\text{or } \frac{R_P}{R_E} = \left(\frac{M_P}{M_E}\right)^{\frac{1}{3}} \quad \text{... (ii)}$$

Weight of the object, $W = mg = m\times\frac{GM}{R^2}$

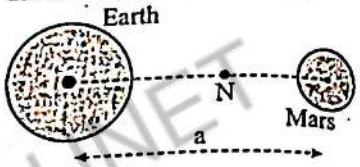
$$\frac{W_P}{W_E} = \frac{mGM_P}{R_P^2}\times\frac{R_E^2}{mGM_E} = \frac{M_P}{M_E}\times\left(\frac{R_E}{R_P}\right)^2$$

$$= \frac{M_P}{M_E}\times\left(\frac{M_E}{M_P}\right)^{\frac{2}{3}} \text{ Using (i)}$$

$$= \left(\frac{M_P}{M_E}\right)^{\frac{1}{3}} = \left(\frac{2M_E}{M_E}\right)^{\frac{1}{3}} = 2^{\frac{1}{3}} \Rightarrow W_P$$

$$= 2^{\frac{1}{3}}W_E = 2^{\frac{1}{3}}W$$

55. (a) $W_1 = 1000$N $\Rightarrow$ Weight of person at surface of earth $W_2 = 400$N $\Rightarrow$ Weight of person at surface of Mars. There will be a neutral point-N where weight will be zero because at this point net gravitational field due to earth and mars is zero.



56. [4] Acceleration due to gravity at $A = \frac{GM}{\left(\frac{3R}{2}\right)^2}$

Acceleration due to gravity at $B = \frac{GM}{R^3}\times r$

$$\because \frac{GM}{\left(\frac{3R}{2}\right)^2} = \frac{GM}{R^3}\times r$$

$$\therefore r = \frac{4R}{9} = OA$$

$$\therefore AB = R - \frac{4R}{9} = \frac{5R}{9}$$

$\Rightarrow OA : AB = 4 : 5 = x : y \Rightarrow x = 4$

57. (c) at pole, weight

$m = 19.6$ kg

at equator, weight $= mg - m\omega^2 R$

$$= 196 - (19.6)\left[\frac{2\pi}{24\times3600}\right]^2\times 6400\times 10$$

$$= 195.33N$$

58. (a)

$$g_h = g_1 = g_s\left(\frac{R}{R+h}\right)^2 = g_s\left(\frac{R}{R+\frac{R}{2}}\right)^2$$

$$= g_s\left(\frac{R}{\frac{3R}{2}}\right)^2 = \frac{4}{9}g_s$$

@FAKE_CBSE_X @RAJ_EDUNET

$\because g_d = g_1 = g_s\left(1-\frac{d}{R}\right), g_h = g_d$

$\frac{4}{9}g_s = g_s\left(1-\frac{d}{R}\right)$

$d = \frac{5R}{9}$

59. (a) $\frac{GM}{(h+R)^2} = \frac{GM}{R^2}\left(1-\frac{h}{R}\right)$

$R^3 = (h+R)^2(R-h)$

Solving $h = \frac{\sqrt{5}-1}{2}R$

60. (a) $g_{equator} = g - \omega^2 R$

$g_h = g_{pole}\left(1-\frac{2h}{R}\right) = g\left(1-\frac{2h}{R}\right)$

$= g - g\left(\frac{2h}{R}\right)$

$\because g_h = g_{equator}$

$g - g\left(\frac{2h}{R}\right) = g - \omega^2 R$

$g\left(\frac{2h}{R}\right) = \omega^2 R \Rightarrow h = \frac{\omega^2 R^2}{2g}$

61. (d) $\frac{GM}{(R+h)^2} = \frac{GM}{2R^2}$

$\Rightarrow R + h = \sqrt{2}R$

$\Rightarrow h = (\sqrt{2}-1)R = 2.6 \times 10^6$ m

62. (a) The gravitational potential energy per unit mass (V) at a height h above the Earth's surface is given by:

$V = -\frac{GM}{R+h}$

And Acceleration at a height h above the earth surface is given by,

$g = \frac{GM_E}{(R_E+h)^2}$

Given $V = -5.12 \times 10^7$ J/kg

and g = 6.4 m/s^2,

Hence,

$-\frac{GM}{R+h} = -5.12\times10^7$ ...(i)

$\frac{GM}{(R+h)^2} = 6.4$ ...(ii)

By solving eqn, (i) and (ii) we get,

$\Rightarrow h = 16 \times 10^5$ m = 1600 km

63. (a) Escape velocity is given as,

$V = \sqrt{\frac{2GM}{R}}$

$V_{planet} = \sqrt{\frac{2GM}{R}} = V$

$V_{Moon} = \sqrt{\frac{2GM\times16}{144R}} = \frac{1}{3}\sqrt{\frac{2GM}{R}}$

Therefore, $V_{Moon} = \frac{V_{planet}}{3} = \frac{V}{3}$

64. (d) Escape velocity of a body from earth = 11.2 km/s.

$R_p = \frac{R_E}{3}, M_p = \frac{M_E}{6}$

$V_e = \sqrt{\frac{2GM_e}{R_e}}$ ...(I)

$V_p = \sqrt{\frac{2GM_p}{R_p}}$ ...(II)

$\frac{V_e}{V_p} = \sqrt{2}$

$V_p = \frac{V_e}{\sqrt{2}} = \frac{11.2}{\sqrt{2}} = 7.9$ km/sec

the escape velocity from the planet is 7.9 km/sec.

65. (a) Given: $h = 318.5 \approx \left(\frac{R_e}{20}\right)$

$[T\cdot E]_i = \frac{-GM_e m}{R_e}$

$[T\cdot E]_f = \frac{-GM_e m}{2(R_e+h)} = \frac{-GM_e m}{2\left(R_e+\frac{R_e}{20}\right)}$

$= \frac{-10GM_e m}{21R_e}$

Change in total mechanical energy

$= \frac{GM_e m}{R_e}\left[1-\frac{10}{21}\right] = \frac{11GM_e m}{21R_e}$

66. (b) From the conservation of energy

$\frac{1}{2}mv_e^2 = \frac{GMm}{R_E}$ $g = \frac{GM}{R_E^2}$

$K = m_g R_E$

67. (a) By using the formula,

$KE = \frac{1}{2}mv^2 = \frac{GMm}{2a}$

$PE = -2KE$

$TE = -KE$

Escape Energy $= \frac{GM}{r}$

68. (b) $v_e = \sqrt{\frac{2GM_p}{R_p}} \Rightarrow v_e \propto \sqrt{\frac{M_p}{R_p}}$

69. (a) Escape velocity of planet

$v_{(escape)\,plant} = \sqrt{\frac{2GM_P}{R_P}}$

$= \sqrt{\frac{2G\left(\frac{M_e}{9}\right)}{\left(\frac{R_e}{2}\right)}}$

$= \frac{v_e\sqrt{2}}{3}$

$\Rightarrow x = 2$

70. (a) Formula of gravitational potential

$V = \frac{GM}{2R^3}\left(3R^2 - r^2\right)$

$\therefore$ At surface, $r = R$,

$V = \left(\frac{GM}{R}\right)$

At centre, $r = 0$

$\therefore V_0 = \frac{3GM}{2R} = \left(\frac{3V}{2}\right)$

71. (b) Formula of escape velocity,

$v_e = \sqrt{\frac{2GM}{R_e}}$

$\therefore v_p = \sqrt{\frac{2GM_p}{R_p}}, v_E = \sqrt{\frac{2GM_E}{R_E}}$

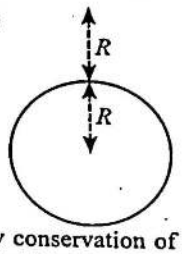
$\frac{v_p}{v_E} = \frac{\sqrt{\frac{2GM_p}{R_p}}}{\sqrt{\frac{2GM_E}{R_E}}} = \sqrt{\frac{R_E}{R_p}\times\frac{M_p}{M_E}}$

$= \sqrt{\frac{1}{4}\times9} = \frac{3}{2}$

$v_p = \frac{3}{2}\times11.2$ km/sec

$= 16.8$ km/sec

72. (a)



By conservation of mechanical energy,
Total initial energy = Total final energy

$Ui + Ki = Uf + Kf$

$-\frac{GMm}{2R} + 0 = -\frac{GMm}{R} + \frac{1}{2}mv^2$

$-\frac{GMm}{2R} + \frac{GMm}{R} = \frac{1}{2}mv^2$

$v = \sqrt{\frac{GM}{R}} = \sqrt{gR}$ $(\because GM = gR^2)$

73. (c) Orbital velocity $v_{orbit} = \sqrt{\frac{GM}{R}}$;

Escape velocity $v_{escape} = \sqrt{\frac{2GM}{R}}$

@FAKE_CBSE_X@RAJ_EDUNET

$$\Delta v = \left(\sqrt{2}-1\right)\sqrt{\frac{GM}{R}} = \left(\sqrt{2}-1\right) \times \sqrt{gR}\left(\because g = \frac{GM}{R^2}\right)$$

$$= 8\left(\sqrt{2}-1\right) km/s$$

74. (*d*) As gravity of the Moon is $\left(\frac{1}{6}\right)^{th}$ of the earth. the rms velocity of molecules is higher than the escape velocity at the Moon due to the low escape velocity. As a result, molecules escape and Moon has no atmosphere.

75. (*d*) Escape velocity is given by

$$V_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2G\rho\frac{4}{3}\pi R^3}{R}} = C\sqrt{\rho}\cdot R$$

$$\Rightarrow \frac{V_{e_1}}{V_{e_2}} = \frac{R_1}{R_2}\sqrt{\frac{\rho_1}{\rho_2}} = \frac{1}{2}$$

$$\frac{R_1^2}{R_2^2}\times\frac{\rho_1}{\rho_2} = \frac{1}{4}$$

Given, $\frac{R_1}{R_2} = \frac{1}{3}$

$$g = \frac{GM}{R^2} = \frac{G\frac{4}{3}\pi R^3 \times \rho}{R^2}$$

$$\Rightarrow \frac{g_1}{g_2} = \frac{\rho_1 R_1}{\rho_2 R_2} = \frac{1}{4}\frac{R_2^2}{R_1^2}\times\frac{R_1}{R_2} = \frac{3}{4}$$

76. (*c*) $U = \frac{-GM_e m}{r}$

Initial gravitational potential energy of the object

$$U_i = \frac{-GM_e m}{R_e}$$

Final gravitational potential energy of the object

$$U_f = \frac{-GM_e m}{(R_e+h)} = \frac{-GM_e m}{R_e+2R_e} = \frac{-GM_e m}{3R_e}$$

Increase in internal energy $\Delta U = U_f - U_i$

$$= \frac{2}{3}\frac{GM_e m}{R_e}, = \frac{2}{3}mgR_e$$

77. (*b*) $-\frac{dV}{dr} = -\frac{k}{r^2} \Rightarrow \int_{10}^{v} dV = \int_2^3 \frac{k}{r^2}dr$

$$V - 10 = k\left[\frac{1}{2}-\frac{1}{3}\right]$$

$$V - 10 = \frac{k}{6} \Rightarrow V = 11 volts$$

(*b*) Loss in PE = Gain in KE

$$\left(-\frac{GMm}{2R}\right)-\left(-\frac{GMm}{R}\right) = \frac{1}{2}mv^2$$

$$\Rightarrow v^2 = \frac{GM}{R} = gR$$

$$\Rightarrow v = \sqrt{gR}$$

79. (*b*) Given, $M_p = 16M_E$ and $R_p = 4R_E$

$$v_{escape} = \sqrt{\frac{2GM}{R}} \Rightarrow v_e \propto \sqrt{\frac{M}{R}}$$

$$\frac{(v_e)_p}{(v_e)_E} = \sqrt{\frac{M_p}{M_e}\times\frac{R_E}{R_p}} = \sqrt{16\times\frac{1}{4}} = 2$$

80. (*a*) $\Delta U = \frac{-Gm_e m}{(R+h)} - \left(-\frac{Gm_e m}{R}\right)$

$$\Rightarrow \Delta U = \frac{GMm}{R} - \frac{GMm}{R+h}$$

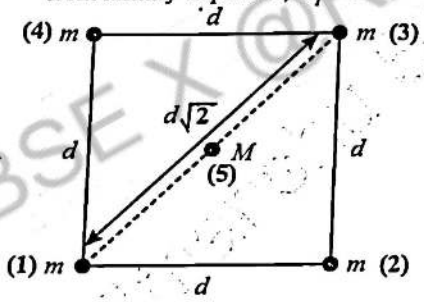
$$= mg_0 R - mg_0\frac{R}{\left(1+\frac{h}{R}\right)}$$

$$= mg_0\left\{1-\frac{1}{\left(1+\frac{3R}{R}\right)}\right\}$$

$$= \frac{3}{4}\times 1\times 10\times 6400 km$$

$$= 48 MJ.$$

81. (*a*) Amount of work done to bring mass from infinity to point 1, $U_i = 0$



2, $U_2 = \frac{-Gm}{d}m$, To bring mass 3

$$U_3 = \frac{-Gmm}{d} - \frac{Gmm}{d\sqrt{2}} = -\frac{Gm}{d}\left[\frac{m}{1}+\frac{m}{\sqrt{2}}\right]$$

To bring mass 4

$$U_4 = \frac{-Gmm}{d} - \frac{Gmm}{d\sqrt{2}} - \frac{Gmm}{d}$$

$$= \frac{-Gm}{d}\left[2m+\frac{m}{\sqrt{2}}\right]$$

To bring mass 5

$$U_5 = -4\times\frac{GmM}{\left(\frac{d}{\sqrt{2}}\right)} = \frac{-Gm}{d}[4\sqrt{2}M]$$

$$U_T = U_1 + U_2 + U_3 + U_4 + U_5$$

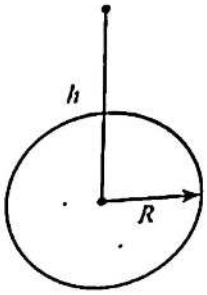
$$U_T = \frac{-Gm}{d}\left[(4+\sqrt{2})m + 4\sqrt{2}M\right]$$

82. (*b*) Escape velocity $V_e = \sqrt{\frac{2GM}{R}}$

From the conservation of energy.

$$\frac{-GMm}{R}+\frac{1}{2}m\lambda^2 V_e^2 = \frac{-GMm}{h}+0$$

$$\Rightarrow \frac{-GMm}{R}+\frac{1}{2}\lambda^2\frac{2GMm}{R} = \frac{-GMm}{h}$$



$$\Rightarrow \frac{\lambda^2}{R}-\frac{1}{R} = \frac{-1}{h}$$

$$\Rightarrow \frac{1}{h} = \frac{1-\lambda^2}{R}, \quad h = \frac{R}{1-\lambda^2}$$

83. (*a*) Escape Velocity, $V_e = \sqrt{\frac{2GM}{R}}$

Let '*h*' be the maximum height.

Using conservation of Mechanical Energy

$$PE_i + KE_i = PE_f$$

$$\Rightarrow \frac{-GMm}{R}+\frac{1}{2}\times m\left(\frac{V_e}{3}\right)^2 = \frac{-GMm}{(R+h)}$$

$$\Rightarrow \frac{GM}{(R+h)} = \frac{GM}{R}-\frac{GM}{9R}$$

$$\Rightarrow \frac{1}{R+h} = \frac{8}{9R} \Rightarrow h = \frac{R}{8}$$

$$= \frac{6400}{8} = 800 km$$

84. [2.3]

Given $MB = 2MA$

As radius is $\Rightarrow$ value same $\Rightarrow \rho B = 2\rho A$

Now after transfer of mass

$$M'_A = \rho_A\frac{4}{3}\pi\left(\frac{R^3}{8}\right) = \frac{M_A}{8}$$

and $M'_B = 2M_A + \frac{7M_A}{8} = \frac{23M_A}{8}$

Now volume of mass lost by star *A* = Volume added to Star *B*

$$\Rightarrow \frac{4}{3}\pi\left(R^3-\left(\frac{R}{2}\right)^3\right) = \frac{4}{3}\pi\left(R_2^3-R^3\right)$$

$$\Rightarrow R^2 = 15^{\frac{1}{3}}\frac{R}{2}$$

Now, $V \propto \sqrt{\frac{M}{R}}$

JEE_FAKE_CBSE X @RAJ_EDUNET

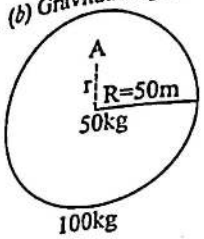
$$\frac{V_B}{V_A}=\sqrt{\frac{M_B}{R_B}\times\frac{R_A}{M_A}}$$

$$\Rightarrow =\sqrt{\frac{23M_A}{8\times15^{\frac{1}{3}}\frac{R}{2}}\times\frac{R}{\frac{M_A}{8}\times2}}$$

$$\Rightarrow \frac{V_B}{V_A}=\sqrt{\frac{10\times2.3}{15^{\frac{1}{3}}}}$$

$$\Rightarrow n=2.3$$

85. (b) Gravitation potential at point A is:



$$V_A=-\frac{GM_1}{r}-\frac{GM_2}{R}$$

$$=\frac{50G}{25}-\frac{100G}{50}=-4G$$

86. (b) At the surface, escape velocity

$$=\sqrt{\frac{2GM}{R_e}}$$

Applying conservation of energy:

$$\Rightarrow\frac{-GMm}{R_e}+\frac{1}{2}m\left(\sqrt{\frac{2GM}{R_e}}\right)^2$$

$$=\frac{-GMm}{r}+\frac{1}{2}mv^2$$

$$\Rightarrow\frac{1}{2}mv^2=\frac{GMm}{r}\Rightarrow v^2=\frac{2GM}{r}$$

$$\Rightarrow v=\sqrt{\frac{2GM}{r}}$$

$$\Rightarrow\frac{dr}{dt}=\sqrt{\frac{2GM}{r}}$$

Time t taken by body to reach at hight h.

$$\therefore\int_{R_e}^{R+h}r^{1/2}dr=\sqrt{2GM}\int_0^t dt$$

$$\Rightarrow\frac{2}{3}\left[(R_e+h)^{3/2}-R_e^{3/2}\right]=\sqrt{2GM}t$$

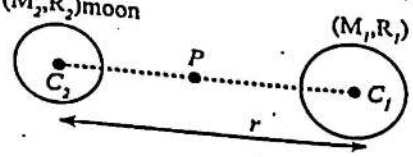
$$\Rightarrow t=\frac{1}{3}\sqrt{\frac{2R_e}{g}}\left[\left(1+\frac{h}{R_e}\right)^{3/2}-1\right]$$

87. (a) Escape velocity, $V_e=\sqrt{\frac{2GM}{R}}$

$$(V_e)_A=(V_e)_B\Rightarrow\frac{M_1}{R_1}=\frac{M_2}{R_2}$$

R is not correct.

88. (b) We have given that the masses and radii of the earth and moon are (M_1, R_1) and (M_2, R_2)



$$KE_P+PE_P=\frac{1}{2}mv_P^2+\left\{\frac{-GM_1m}{(r/2)}-\frac{GM_2m}{r/2}\right\}$$

At infinity

$$KE_\infty+PE_\infty=0+0$$

So, according to conservation of mechanical energy

$$KE_P+PE_P=KE_\infty+PE_\infty$$

$$\frac{1}{2}mv_P^2-\frac{2Gm}{r}(M_1+M_2)=0+0$$

$$\Rightarrow v_P=\sqrt{\frac{4G(M_1+M_2)}{r}}$$

89. (b) Inside a uniform spherical shell, gravitational field is zero everywhere and gravitational potential is constant but not zero, every where

90. [64]

Escape velocity of a planetary system is given by,

$V_{es}=\sqrt{\frac{2CM}{R}}$ Where, M is the mass of the planet, R is the radius of the planet

$$\Rightarrow Ves\sqrt{R}=\text{constant}$$

$$\Rightarrow V_{es}\cdot\sqrt{R}=10V_{es}\sqrt{R'}$$

$$\Rightarrow R'=\frac{R}{100}=64\text{ km}$$

Hence, Thus, the radius in kilometres to which the present radius of the earth (R = 6400 km) is to be compressed so that the escape velocity is increased to ten times is 64 km.

91. [10]

Using conservation of energy:

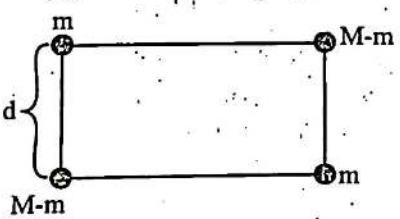
$$\Rightarrow\frac{1}{2}mv_i^2-\frac{Gmm}{R}=0-\frac{Gmm}{11R}$$

$$\Rightarrow v_i^2=\frac{20}{11}\frac{Gm}{11R}$$

$$V_e=\sqrt{\frac{2GM}{R}}$$

$$\therefore V_i=\sqrt{\frac{10}{11}}v_e$$

92. [2]



$$U=-\frac{Gm(M-m)}{d}\times4+-2\times\frac{Gm^2}{(d\sqrt{2})^2}$$

For U to be maximum,

$$\frac{dU}{dm}=0\Rightarrow m=\frac{M}{2}\Rightarrow\frac{M}{m}=2$$

93. [3] According to question the given data is $\frac{x}{5}\frac{GM^2}{R}$ ...(I)

Energy given = U_f-U_i

$$=0-\left(-\frac{3}{5}\frac{GM^2}{R}\right)=\frac{3}{5}\frac{GM^2}{R}\quad\text{...(II)}$$

Comparing eq.(I) to eq.(II) we get $x=3$

94. (a) Since, net force is zero so momentum is conserved.

$$\frac{m}{2}\frac{v}{2}+mv=\left(m+\frac{m}{2}\right)v_f$$

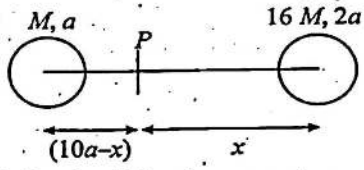
$$v_f=\frac{5mV}{4\times\frac{3m}{2}}=\frac{5V}{6}$$

$v_f<v_{orb}\,(=v)$ thus the combined mass will go on to an elliptical path.

95. (c) $\int_0^V dV=-\int_\infty^x E.dx$

$$V=-A\int_\infty^x\frac{xdx}{(x^2+a^2)^{3/2}}=\frac{A}{(x^2+a^2)^{1/2}}$$

96. (a)



Velocity should be given so as to reach a point where field is zero.

$$\frac{16M}{x^2}=\frac{M}{(10a-x)^2}$$

$$x=8a$$

By CoE

$$-\frac{GMm}{8a}-\frac{16GMm}{2a}+\frac{1}{2}mv^2$$

$$=-\frac{16GMm}{8a}-\frac{GMm}{2a}+0$$

$$\frac{1}{2}mv^2=\frac{45GMm}{8a}$$

$$v=\frac{3}{2}\sqrt{\frac{5GM}{a}}$$

97. (d) $v_e=\sqrt{\frac{2GM}{R}}$

$$\therefore\frac{v_1}{v_2}=\frac{\sqrt{\frac{2GM}{R}}}{\sqrt{\frac{2GM/2}{R/2}}}=1=\frac{n}{4}\Rightarrow n=4$$

@FAKE_CBSE_X @RAJ_EDUNET

98. (d) $v_o = \sqrt{\frac{GM}{R}}$

$v_e = \sqrt{\frac{2GM}{R}}$

$\frac{v_0}{v_e} = \frac{1}{\sqrt{2}}$

99. [16]

$KE_i + PE_i = KE_f + PE_f$

$\frac{1}{2}mu_0^2 + \left(-\frac{GMm}{10R}\right) = \frac{1}{2}mv^2 + \left(-\frac{GMm}{R}\right)$

$v^2 = u_0^2 + \frac{2GM}{R}\left[1 - \frac{1}{10}\right]$

$v = \sqrt{u_0^2 + \frac{9}{5}\frac{GM}{R}}$

$= \sqrt{12^2 + \left(\frac{9}{5}\right)\frac{(11.2)^2}{2}}$

$= \sqrt{144 + 0.9(11.2)^2} = \sqrt{256.896}$

$= 16.028$ km/s $= 16$

100. (d) $\frac{1}{2}mv^2 + \frac{2(-GMm)}{r} = 0$

$V^2 = \frac{4GM}{r} = \frac{4 \times 6.67 \times 10^{-11} \times 3 \times 10^{31}}{2 \times 10^{11}}$

$V = 20\sqrt{2} \times 10^4 m/s = 2.828 \times 10^5$ m/s

101. (b) minimum energy required (E) = – (Potential energy of object at surface of earth)

$= -\left(-\frac{GMm}{R}\right) = \frac{GMm}{R}$

Now,

$\rho.\frac{4}{3}\pi R_e^3 = 64.\frac{4}{3}\pi R_m^3 \Rightarrow R_e = 4R_m$

$M_{earth} = 64\, M_{moon}$

$\therefore \frac{E_{moon}}{E_{earth}} = \frac{M_{moon}}{M_{earth}} \cdot \frac{R_{earth}}{R_{moon}} = \frac{1}{64} \times \frac{4}{1}$

$\Rightarrow E_{moon} = \frac{E}{16}$

102. (c) Here T_A and T_B is the time period of the two planet A and B.

For planet A, $\frac{\pi r_1^2}{T_A} = \frac{L}{2m_1}$ ...(i)

(Areal velocity)

For planet B, $\frac{\pi r_2^2}{T_B} = \frac{3L}{2m_2}$ ...(ii)

(Areal velocity)

$\Rightarrow \frac{T_A}{T_B} = 3 \cdot \frac{m_1}{m_2} \cdot \left(\frac{r_1}{r_2}\right)^2$

$\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_1}{r_2}\right)^3 \Rightarrow \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{T_A}{T_B}\right)^{\frac{4}{3}}$

$\Rightarrow \frac{1}{27} \cdot \left(\frac{m_2}{m_1}\right)^3 = \left(\frac{T_A}{T_B}\right)$

103. (d) Let, m be mass of satellite & M mass of earth

Total energy $= \frac{-GMm}{2(2R)}$

According to question $\frac{10^4 R}{6} J$ of energy is supplied to the satellite

$\Rightarrow \frac{-GMm}{4R} + \frac{10^4 R}{6} = \frac{-GMm}{2r}$

where r is new radius of revolving and

$g = \frac{GM}{R^2}$

$-\frac{mgR}{4} + \frac{10^4 R}{6} = -\frac{mgR^2}{2r}$ ($m = 10^3$ kg)

$-\frac{10^3 \times 10 \times R}{4} + \frac{10^4 R}{6}$

$= -\frac{10^3 \times 10 \times R^2}{2r}$

$-\frac{1}{4} + \frac{1}{6} = -\frac{R}{2r}$

$\therefore r = 6R$

104. (c) speed of the satellite moving around a planet,

$v = \sqrt{\frac{GM}{R}}$

$\frac{v_A}{v_B} = \sqrt{\frac{R_B}{R_A}} = \sqrt{\frac{R}{4R}} = \frac{1}{2}$

$v_B = 2v_A = 6v$

105. (d) The time period of the satellite,

$T = \frac{2\pi r^{3/2}}{\sqrt{GM}}$

The ratio of the time period,

$\frac{T_1}{T_2} = \left(\frac{r_1}{r_2}\right)^{3/2}\left(\frac{M_2}{M_1}\right)^{1/2}$

$\frac{6}{24} = \frac{(r_1)^{3/2}}{(4.2 \times 10^4)^{3/2}}\left(\frac{M}{M/4}\right)^{1/2}$

$r_1 = 1.05 \times 104$ km

106. (b) Gravitational force provides contripetal force

$\Rightarrow \frac{GMm}{(R+h)^2} = \frac{mv^2}{(R+h)}$

$v^2 = \frac{GM}{(R+h)}$ ...(i)

from $v = (R+h)\omega$

$\Rightarrow v = (R+h)\frac{2\pi}{T}$ ...(ii)

$\Rightarrow GM = gR^2$ ...(iii)

Put value from (ii) & (iii) in eq. (i)

$\Rightarrow \frac{gR^2}{(R+h)} = (R+h)^2\left(\frac{2\pi}{T}\right)^2$

$\Rightarrow \left[\frac{T^2R^2g}{(2\pi)^2}\right]^{1/3} - R = h$

107. (d) Let the mass of the satellites be M_A & M_B and Mass and radius of earth be M_e and R_e respectively

Then,

$P.E = -\frac{GM_eM_A}{R_e} \Rightarrow P.E \propto M_e \cdot M_A$

$K.E = +\frac{GM_eM_A}{2R_e} \Rightarrow K.E \propto M_e \cdot M_A$

$T.E = -\frac{GM_eM_A}{2R_e} \Rightarrow T.E \propto M_e \cdot M_A$

$Speed = v = \sqrt{\frac{GM_e}{R_e}} \Rightarrow v \propto \sqrt{M_e}$

Speed of satellite is Independent of mass of satellite (M_A or M_B).

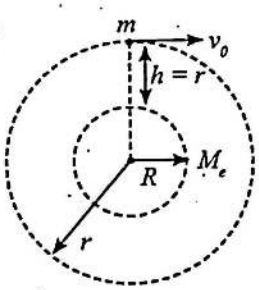
108. (c) Revolving radius,

$r = R + R = 2R$

Time period, $T = \frac{2\pi r}{v} = \frac{2\pi r}{\sqrt{\frac{4M}{r}}}$

$T = \frac{2\pi(2R)}{\sqrt{\frac{GM}{2R}}} = T = \sqrt{32R}$

109. (d)



Oribital speed, $v_0 = \sqrt{\frac{GM_e}{r}}$

Orbital angular momentum,

$L_0 = mv_0r$

$\therefore L = m\sqrt{\frac{GM_e}{r}}.r \Rightarrow L \propto r^{\frac{1}{2}}$

@FAKE_CBSE_X @RAJ_EDUNET

So new distance from centre $r' = r + 8r$
$= 9r$

Now angular momentum $L' \propto (r')^{\frac{1}{2}}$

$\therefore \frac{L}{L'} = \frac{r^{1/2}}{(9r)^{1/2}} = \frac{1}{3}$

$L' = 3L$

110. (d) The path of the planets as they orbit the sun is elliptical. As a result, their linear speed fluctuates. Thus their linear speed is not constant

111. (b) Energies of orbiting satellite

Total energy, $E = \frac{-GMm}{2R}$

Potential energy, $U = \frac{-GMm}{R}$

Kinetic energy, $K = \frac{GMm}{2R}$

$\therefore K = -E = -2U$

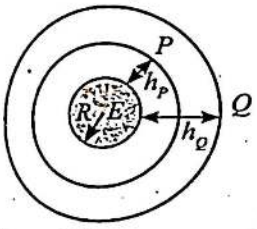
112. (c) Orbital speed, $v = \sqrt{\frac{GM}{r}}$ (M : Mass of Earth)

$\Rightarrow$ Orbital speed is independent of mass of the satellite.

$v \propto \frac{1}{\sqrt{r}}$

$\Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{r_2}{r_1}} = \sqrt{\frac{3r}{r}} = \sqrt{3} : 1$

113. (a) Given, $\frac{g_P}{g_Q} = \frac{36}{25}$



$\frac{g_P}{g_Q} = \frac{\frac{GM}{r_P^2}}{\frac{GM}{r_Q^2}} = \left(\frac{r_Q}{r_P}\right)^2$

$\frac{36}{25} = \left(\frac{r_Q}{r_P}\right)^2 \Rightarrow \frac{r_Q}{r_P} = \frac{6}{5}$

$r_Q = \frac{6}{5} r_P$

$R + h_Q = \frac{6}{5}\left(R + \frac{R}{3}\right)$

$h_Q = \frac{24}{15}R - R = \frac{9}{15}R = \frac{3}{5}R$

114. [2] $\frac{v_1}{v_2} = \frac{\sqrt{\frac{GM}{R_1}}}{\sqrt{\frac{GM}{R_2}}} = \sqrt{\frac{R_2}{R_1}} = \sqrt{\frac{800}{3200}} = \frac{1}{2}$

115. [4] Let at some point situated at a distance x from a smaller planet, the net force on the satellite will be zero therefore,

$\frac{GM}{x^2} = \frac{G \times 9M}{(8R - x)^2}$

$\frac{1}{x^2} = \frac{9}{(8R - x)^2}$

$\frac{8R - x}{x} = 3$

$x = 2R$

Using conservation of mechanical energy between projection point and point P.

$\frac{1}{2}mv^2 - \frac{GMm}{R} - \frac{G(9M)m}{7R}$

$= 0 - \frac{GMm}{2R} - \frac{G(9M)m}{6R}$

$\frac{1}{2}mv^2 = \frac{2GMm}{7R} \Rightarrow v = \sqrt{\frac{4GM}{7R}} \Rightarrow a = 4$

116. (b) $\frac{dM}{dV} = \frac{K}{r}$

$dM = \frac{K}{r} \times dV$

$dM = \frac{K}{r} \times 4\pi r^2 dr$

$M = \int_0^R \left(\frac{K}{r}\right) 4\pi r^2 dr$

$M = 2\pi K R^2$

$\because m\omega^2 R = \frac{GMm}{R^2}$

$\omega^2 R = \frac{GM}{R^2}$

$\omega^2 R = 2G\pi K; \omega^2 = \frac{2G\pi K}{R}$

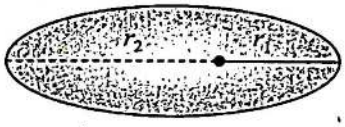
$\omega^2 \propto \frac{1}{R}; T^2 \propto R$

117. (a) Total energy $E = \frac{-GMm}{2a}$

$\therefore \frac{1}{2}m \times \left(\frac{3}{2}\frac{GM}{R}\right) - \frac{GMm}{R} = \frac{-GMm}{2a}$

$\Rightarrow a = 2R$

Major axis $= 4R$



$r_1 = R_2 \Rightarrow r_2 = 3R$

118. (c) $F = \frac{dp}{dt} = \left(\frac{dM}{dt}\right)v + M(t)\frac{dv}{dt}$

$= bv^3 + M(t)a$

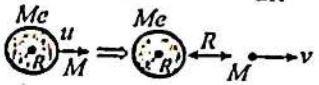
$\Rightarrow a = -\frac{bv^3}{M(t)}$

119. (a) $\frac{V_{min}}{V_{max}} = \frac{(1-e)}{(1+e)} = \frac{1}{6}$

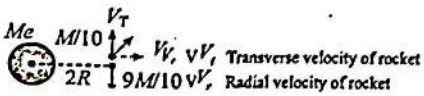
$\frac{r_{min}}{r_{max}} = \frac{(1-e)}{(1+e)} = \frac{1}{6}$

120. (b)

$\frac{-GMeM}{R} + \frac{1}{2}Mu^2 = \frac{-GMeM}{2R} + \frac{1}{2}Mv^2$



$v = \sqrt{u^2 - \frac{GM_e}{R}}$



$\frac{M}{10}V_T = \frac{9M}{10}\sqrt{\frac{GM_e}{2R}}$

$\frac{M}{10}V_r = M\sqrt{u^2 - \frac{GM_e}{R}}$

Kinetic energy

$= \frac{1}{2}\frac{M}{10}\left(V_T^2 + V_r^2\right)$

$= \frac{M}{20}\left(81\frac{GM_e}{2R} + 100u^2 - 100\frac{GM_e}{R}\right)$

$= \frac{M}{20}\left(100u^2 - \frac{119GM_e}{2R}\right)$

$= 5M\left(u^2 - \frac{119GM_e}{200R}\right)$

121. (b)

$V = \sqrt{\frac{GM}{r}} = \sqrt{\frac{(6.67 \times 10^{-11})(8 \times 10^{22})}{2.02 \times 10^6}}$

$V = 1.625 \times 10^3$

$T = \frac{2\pi r}{V}$ & $n \times T = 24 \times 60 \times 60$

$n\left[\frac{2\pi(2.02 \times 10^6)}{1.625 \times 10^3}\right] = 24 \times 3600$

$n = \frac{24 \times 3600 \times 1.625 \times 10^3}{2\pi(2.02 \times 10^6)} = 11$

122. (d) $\Delta v = \sqrt{\frac{2GM}{R}} - \sqrt{\frac{GM}{R}} = (\sqrt{2} - 1)\sqrt{gR}$

123. (b) Energy required to take a satellite to a height h above earth surface,

$E_1 = -\frac{GMm}{R+h} - \left(-\frac{GMm}{R}\right)$

Kinetic energy required for the satellite to be in a circular orbit at the same height,

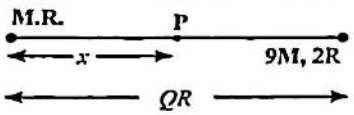
@FAKE_CBSE_X @RAJ_EDUNET

$$E_2 = \frac{1}{2}m\left(\sqrt{\frac{GM}{R+h}}\right)^2 = \frac{GMm}{2(R+h)}$$

Here, $E_1 = E_2$ so $h = \frac{R}{2}$.

124. (*b*) $KE_A = \frac{1}{2}m\left(\frac{GM}{R}\right)$

$$KE_B = \frac{1}{2}(2m)\left(\frac{GM}{2R}\right) \Rightarrow \frac{KE_A}{KE_B} = 1$$



125. (*b*) Initially, kinetic energy

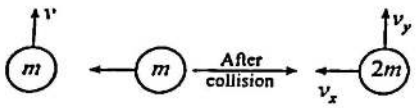
$$= \frac{1}{2}mv^2 = \frac{1}{2}m\frac{GM_e}{r}$$

By conservation of *M.E.*,

$$\frac{-GM_em}{r} + KE = 0$$

$$KE = \frac{GM_em}{r} = mv^2$$

126. (*b*)



$$2mv_x = mv$$

$$\Rightarrow v_x = \frac{v}{2}$$

$$v_y = \frac{v}{2}$$

$$v_{net} = \sqrt{v_{x2} + v_{y2}} = \frac{v}{\sqrt{2}}$$

So, path will be elliptical.

127. [25] Time to complete 1 revoluation = 200 days using kepler's third law

$T^2 \propto r^3$

$$\frac{T_1^2}{r_1^3} = \frac{T_2^2}{r_2^3}$$

$$\frac{(200)^2}{r^3} = \frac{T_2^2}{\left(\frac{r}{4}\right)^3}$$

$$\frac{200\times200}{4\times4\times4} = T_2^2$$

$$T_2 = \frac{200}{4\times2} = 25 \text{ days}$$

128. (*b*) Angular frequency $\omega \propto \frac{1}{T}$

Tearth = 365 days 4 hour

Tmoon = 27 days

$\Rightarrow \omega moon > \omega earth$

129. (*a*) $F = \frac{GMm}{R^{3/2}} = m\omega^2 R$

$$\omega^2 \propto \frac{1}{R^{5/2}} \quad \because T = \frac{2\pi}{\omega} \text{ so}$$

$$T^2 \propto R^{5/2}$$

130. (*c*) $\because T^2 \propto R^3$

$$\Rightarrow \left(\frac{T_1}{T_2}\right)^2 = \left(\frac{R_1}{R_2}\right)^3$$

$$\Rightarrow \left(\frac{1}{2.83}\right)^2 = \left(\frac{1.5\times10^6}{R_2}\right)^3$$

$$\Rightarrow R_2 = 8^{1/3}\times1.5\times10^6 = 3\times10^6 \, km$$

131. (*d*) Using kepler's law of planetary motion,

$$\frac{T_1^2}{T_2^2} = \frac{R_1^3}{R_2^3}$$

$$\Rightarrow \left(\frac{T_1}{T_2}\right)^2 = \left(\frac{R}{\frac{R}{4}}\right)^3$$

$$\Rightarrow T_2^2 = \frac{T_1^2}{64}$$

$$\therefore T_2 = \frac{24}{8} = 3 \text{ hours}$$

132. (*a*) Using Newton's law of gravitation,

$$F = \frac{Gm_1m_2}{r^2} \Rightarrow F \propto \frac{1}{r^2}$$

and, using Kepler's third law,

$T^2 \propto a^3$

133. (*d*) $T^2 \propto R^3$

Given, $R_2 = 3R_1$

$$\Rightarrow \frac{T_2}{T_1} = \left(\frac{R_2}{R_1}\right)^{\frac{3}{2}}(3)^{\frac{3}{2}} \Rightarrow T_2$$

$$= 3\sqrt{3}T_1 = 3\sqrt{3} \text{ year}$$

134. (*c*) Since, $T^2 \propto R^3$

$$\Rightarrow \frac{T_A^2}{T_B^2} = \frac{r_A^3}{r_B^3} \text{ or } r_A^3 = 4r_B^3$$

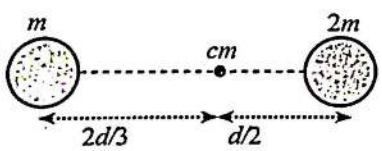
135. (*b*) We have given, $T_1 = 7hr$, $r_2 = 3r_1$.

We have to find T_2 when $r_2 = 3r_1$.

$$\therefore T^2dr^3 \Rightarrow \left(\frac{T_2}{T_1}\right)^2 = \left(\frac{r_2}{r_1}\right)^3 = \left(\frac{3r_1}{r_1}\right)^3 = 27$$

$$\Rightarrow T_2 = \sqrt{27}T_1 = \sqrt{27}\times7 \approx 36 \text{ hrs}$$

136. (*c*)



From the center of mass formula,

$mr_1 = 2mr_2$

$\Rightarrow r_1 = 2(d - r_1) = \frac{2}{3}d$

Since, gravitational force between masses = Centripetal force

$$\therefore m\omega^2 \cdot \frac{2d}{3} = \frac{G\times m\times2m}{d^2} \Rightarrow \omega = \sqrt{\frac{3Gm}{d^3}}$$

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{d^3}{3Gm}}$$

137. (*a*) Using conservation of angular momentum, we can write

$$v_1 = \frac{v_2r_2}{r_1} = \frac{8\times10^{10}}{1.6\times10^{12}}\times6\times10^4$$

$$= 3\times10^3 \text{ m/s}$$

138. (*c*) $T^2 = \alpha R^3$

$$\Rightarrow \left(\frac{T_2}{T_1}\right)^2 = \left(\frac{R_2}{R_1}\right)^3$$

$$\Rightarrow T_2 = 9^{\frac{3}{2}}T = 27T$$

139. (*d*) We know that, $\omega = \frac{2\pi}{T} \Rightarrow \frac{\omega_1}{\omega_2} = \frac{T_2}{T_1} = 8$

140. (*b*) Time period of revolution, $T^2 = \frac{4\pi^2r^3}{GM}$

$$\Rightarrow M = \frac{4\pi^2r^3}{G\times T^2} = \frac{6\times10^{11}\times\left(9\times10^6\right)^3}{(450\times60)^2}$$

$$= 6\times10^{23} kg$$

141. (*c*) At the closest distance, the speed will be maximum. ($x_1 < x_2$)

Applying the conservation of angular momentum, $mv_0x_2 = mvx_1$

$$v = \frac{v_0x_2}{x_1}$$

142. (*b*) We know that the areal velocity $= \frac{dA}{dt}$

For small angle ($d\theta$) swept by the planet

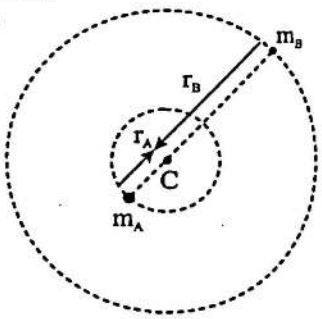
Area, $dA = \frac{1}{2}(r)(rd\theta)$

$\therefore$ Areal velocity,

$$\frac{dA}{dt} = \frac{1}{2}r^2\frac{d\theta}{dt} = \frac{1}{2}\left(\frac{Mr^2\omega}{M}\right) = \frac{L}{2M}$$

143. (*d*) In elliptical orbit, areal velocity is constant

144. (*a*)



@FAKE_CBSE_EX @RAJ_EDUNET

In the diagram, C is the centre of mass of given binary star system. Since, C is the centre of mass. Two forces, gravitational force and centripetal force are acting on each star, and these forces are responsible for rotation of the star. Therefore,

$$m_A\omega_A^2 r_A = \frac{Gm_Bm_A}{(r_A+r_B)^2} = \frac{Gm_Bm_A}{r^2}$$

$$\Rightarrow m_A\omega_A^2 \times = \frac{m_B}{(m_A+m_B)}r = \frac{Gm_Bm_A}{r^2}$$

$$\Rightarrow \omega_A^2 = \frac{G(m_A+m_B)}{r^3}$$

$$\Rightarrow \omega_A = \sqrt{\frac{G(m_A+m_B)}{r^3}}$$

Similarly we can show that

$$\omega_B = \sqrt{\frac{G(m_A+m_B)}{r^3}}$$

Hence their angular velocity will be same, time period will be same, i.e. $T_A = T_B$

145. (*b*) Time period of a satellite revolving around the earth,

$$T = 2\pi\sqrt{\frac{r^3}{GM_e}}$$

$$T_B - T_A = \frac{2\pi}{\sqrt{GM_e}}\left(r_B^{3/2} - r_A^{3/2}\right)$$

$$= \frac{2\times 3.14}{\sqrt{6.67\times10^{-11}\times6\times10^{24}}}\left[(8\times10^6)^{3/2} - (7\times10^6)^{3/2}\right]$$

$$= 1.3\times10^3\ s.$$

146. [9] Circular orbits

$$T = 2\pi\sqrt{\frac{R^3}{GM_S}}$$

Binary stars

$$nT = 2\pi\sqrt{\frac{(9R)^3}{G(3M_S+6M_S)}}$$

$$n\times2\pi\sqrt{\frac{R^3}{GM_S}} = 9\times2\pi\sqrt{\frac{R^3}{GM_S}}$$

147. (*b*) Given that, $R_1 = R$, $R_2 = 1.02R$

We know that, time period of satellite,

$$\Rightarrow T\propto R^{\frac{3}{2}} \Rightarrow \frac{T_2}{T_1} = \left(\frac{R_2}{R_1}\right)^{\frac{3}{2}} = \frac{(1.02R)^{\frac{3}{2}}}{R^{\frac{3}{2}}}$$

$$= (1.02)^{\frac{3}{2}} = (1+0.02)^{\frac{3}{2}}$$

$$\Rightarrow \frac{T_2}{T_1} = \left(1+\frac{3}{2}\times0.02\right) \Rightarrow T_2 = (1+0.03)T_1$$

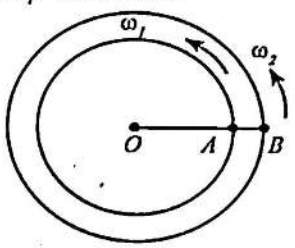
$$\Rightarrow \Delta T = (0.03)T_1$$

Therefore, percentage difference in the time periods of the two satellites

$$= \frac{\Delta T}{T_1}\times100 = (0.03)\times100 = 3\%$$

148. [3] $T_1 = 1$ hour [For A satellite]

So $\omega_1 = 2\pi$ rad/hour



$T_2 = 8$ hour [For B satellite]

$\omega_2 = \frac{\pi}{4}$ rad/hour

As $T^2 \propto R^3$

$$\left(\frac{R_1}{R_2}\right)^3 = \left(\frac{T_1}{T_2}\right)^2 = \left(\frac{1}{8}\right)^2$$

$$\frac{R_1}{R_2} = \left(\frac{1}{8}\right)^{2/3} = \left(\frac{1}{2}\right)^2$$

$\Rightarrow R_2 = 8\times10^3$ Km

$V_1 = \omega_1R_1 = 4\pi\times10^3$ Km/h

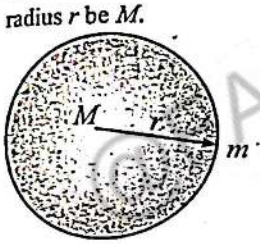
$V_2 = \omega_2R_2 = 2\pi\times10^3$ Km/h

$$\text{Relative } \omega = \frac{V_1-V_2}{R_2-R_1} = \frac{2\pi\times10^3}{6\times10^3}$$

$$\Rightarrow \frac{\pi}{3}\text{ rad/hour} \Rightarrow x = 3$$

JEE-Advanced

1. (*d*) Let total mass included in a sphere of radius r be M.



For a particle of mass m,

$$\frac{GMm}{r^2} = \frac{mv^2}{r} \Rightarrow \frac{GMm}{r} = 2K$$

$$\Rightarrow M = \frac{2Kr}{Gm} \quad \therefore dM = \frac{2Kdr}{Gm}$$

$$\Rightarrow (4\pi r^2dr)\rho = \frac{2Kdr}{Gm} \Rightarrow \rho = \frac{K}{2\pi r^2Gm}$$

$$\therefore n = \frac{\rho}{m} = \frac{K}{2\pi r^2m^2G}$$

2. (*c*) For $r \le R$, $\frac{mv^2}{r} = \frac{GmM}{r^2}$ ...(*i*)

Here, $M = \left(\frac{4}{3}\pi r^3\right)\rho_0$

Putting in equ (*i*), we get $v \propto r$

Hence, $v - r$ graph is a straight line passing through the origin

For $r > R$,

$$\frac{mv^2}{r} = \frac{Gm\left(\frac{4}{3}\pi R^3\right)\rho_0}{r^2} \text{ or, } v\propto\frac{1}{\sqrt{r}}$$

3. (*a*) When something orbits in space then its gravitational force is balanced by centripetal force.

Therefore, it seems like no force acts and its weightlessness. Force acting on the astronaut is used in providing required centripetal force, thus he feels weightlessness, as he is in a state of free fall.

Therefore the option (*a*) is correct.

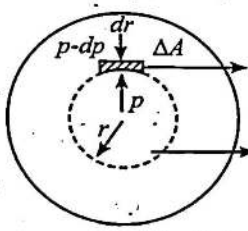
4. (*b, c*) Gravitational field is calculated at a distance r due to mass m

$$E = \frac{\frac{4G\rho}{3}\pi r^3}{r^2} = \frac{4G\rho\pi r}{3}$$

Take a small element of width dr and area ΔA at a pressure force on this element outwards = gravitation on dm from m inwards

$(dP)\,\Delta A = E(dm)$

$$-dP\cdot\Delta A = \left(\frac{4}{3}G\rho\pi r\right)(\Delta A)\times\rho(dr)$$



Mass = dm
$= (\Delta A)(dr)\rho$
= Mass
$= m$
$= \rho\left(\frac{4}{3}\pi r^3\right)$

$$-\int_0^P dP = \int_R^r\left(\frac{4G\rho^2\pi}{3}\right)rdr$$

$$-P = \frac{4G\rho^2\pi}{6}[r^2-R^2]$$

$$\Rightarrow P = c(R^2-r^2)$$

$$r = \frac{3R}{4}, P_1 = c\left(R^2-\frac{9R^2}{16}\right) = c\left(\frac{7R^2}{16}\right)$$

CRACK_CBSE_EXAM@RAJ_EDUNET

$$r=\frac{2R}{3}, P_2=c\left(R^2-\frac{4R^2}{9}\right)=c\left(\frac{5R^2}{9}\right)$$

$$\frac{P_1}{P_2}=\frac{63}{80}$$

$$r=\frac{3R}{5}, P_3=c\left(R^2-\frac{9}{25}R^2\right)=c\left(\frac{16R^2}{25}\right)$$

$$r=\frac{2R}{5}, P_4=c\left(R^2-\frac{4R^2}{25}\right)=c\left(\frac{21R^2}{25}\right)$$

$$\frac{P_3}{P_4}=\frac{16}{21}$$

5. (a, b) For $r<R$, $F=\frac{GM}{R^3}\cdot r$ or $F\propto r$

$\frac{F_1}{F_2}=\frac{r_1}{r_2}$ for $r_1<R$ and $r_2<R$

and for $r\geq R$, $F=\frac{GM}{r^2}$

or $F\propto\frac{1}{r^2}\Rightarrow\frac{F_1}{F_2}=\frac{r_2^2}{r_1^2}$ for $r_1>R$ and $r_2>R$

6. [7] For point mass at distance $r=3l$

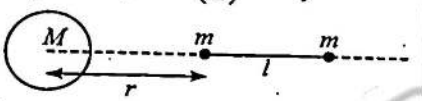
$$\frac{GMm}{(3l)^2}-\frac{Gm^2}{l^2}=ma$$

For point mass at distance $r=4l$

$$\frac{GmM}{(4l)^2}+\frac{Gm^2}{l^2}=ma$$

calculating the two equations, we get

$$\frac{GmM}{9l^2}-\frac{Gm^2}{l^2}=\frac{GmM}{(4l)^2}+\frac{Gm^2}{l^2}$$

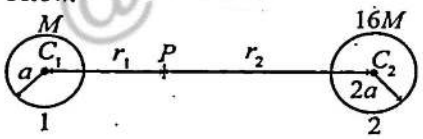


$$\frac{7GMm}{144}=\frac{2Gm^2}{l^2}$$

$$m=\frac{7M}{288}$$

Therefore, $k=7$.

7. Let there are two stars 1 and 2 as shown below.



Let P is a point between C_1 and C_2, where gravitational field strength is zero or at P field strength due to star 1 is equal and opposite to the field strength due to star 2. Hence,

$$\frac{GM}{r_1^2}=\frac{G(16M)}{r_2^2}$$

or $\frac{r_2}{r_1}=4$

also $r_1+r_2=10a$

$$\therefore\ r_2=\left(\frac{4}{4+1}\right)(10a)=8a$$

and $r_1=2a$

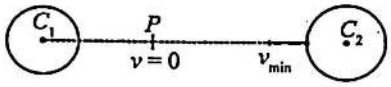
Now, the body of mass m is projected from the surface of larger star towards the smaller one. Between C_2 and P it is attracted towards 2 and between C_1 and P it will be attracted towards 1. Therefore, the body should be projected to just cross point P. Beyond that point the particle is attracted towards the smaller star itself.

From conservation of mechanical energy

$\frac{1}{2}mv_{min}^2$

= Potential energy of the body at P − Potential energy at the surface of larger star.

$$\therefore\ \frac{1}{2}mv_{min}^2=\left[-\frac{GMm}{r_1}-\frac{16GMm}{r_2}\right]-\left[-\frac{GMm}{10a-2a}-\frac{16GMm}{2a}\right]$$



$$=\left[-\frac{GMm}{2a}-\frac{16GMm}{8a}\right]-\left[-\frac{GMm}{8a}-\frac{8GMm}{a}\right]$$

or $\frac{1}{2}mv_{min}^2=\left(\frac{45}{8}\right)\frac{GMm}{a}$

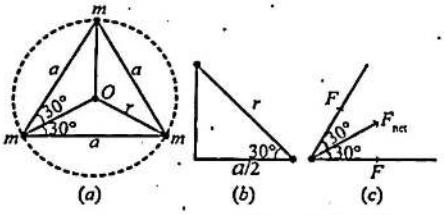
$$\therefore\ v_{min}=\frac{3\sqrt{5}}{2}\left(\sqrt{\frac{GM}{a}}\right)$$

8. Centre should be at O and radius r.

We can calculate r from figure (b).

$$\frac{a/2}{r}=\cos30^\circ=\frac{\sqrt{3}}{2}\Rightarrow\therefore r=\frac{a}{\sqrt{3}}$$

Further net force on any particle towards centre



$$F_{net}=2F\cos30^\circ=2\left(\frac{Gm^2}{a^2}\right)\left(\frac{\sqrt{3}}{2}\right)$$

$$=\frac{\sqrt{3}Gm^2}{a^2}$$

This net force should be equal to $\frac{mv^2}{r}$

$$\therefore\ \frac{\sqrt{3}Gm^2}{a^2}=\frac{mv^2}{a/\sqrt{3}}\Rightarrow v=\sqrt{\frac{Gm}{a}}$$

Time period of circular motion

$$T=\frac{2\pi r}{v}=\frac{2\pi(a/\sqrt{3})}{\sqrt{Gm/a}}=2\pi\sqrt{\frac{a^3}{3Gm}}$$

9. (b) The given parameters are:

$R_{planet}=\frac{R_{earth}}{10}$ and density,

$$\rho=\frac{M_{earth}}{\frac{4}{3}\pi R_{earth}^3}$$

$$=\frac{M_{planet}}{\frac{4}{3}\pi R_{planet}^3}\Rightarrow M_{planet}=\frac{M_{earth}}{10^3}$$

$$g_{surface\ of\ planet}=\frac{GM_{planet}}{R_{planet}^2}=\frac{GM_{earth}\cdot10^2}{10^3\cdot R_{earth}^2}$$

$$=\frac{GM_{earth}}{10R_{earth}^2}=\frac{g_{surface\ of\ earth}}{10}$$

$$g_{depth\ of\ planet}=g_{surface\ of\ planet}\left(\frac{x}{R}\right)$$

where, x = distance from the centre of the planet. Therefore the net force on the wire given by:

$$F=\int_{\frac{4R}{5}}^{R}\lambda dx g\left(\frac{x}{R}\right)=\frac{\lambda g}{R}\left[\frac{x^2}{2}\right]_{\frac{4R}{5}}^{R}$$

$g=g_{surface\ of\ planet}$, $R=R_{planet}$

Here, λ = linear mass density

Now putting the given values, we get

$$F=\frac{\lambda g_{surface\ of\ earth}\times10}{10\times R_{earth}}\left[\frac{9R_{earth}^2}{5000}\right]$$

$$=\frac{(10^{-3})(1)(10)\,9(6\times10^6)}{5000}=108N$$

10. (d) When pendulum taken away from earth then g decreases so T increases by relation $T\propto\frac{1}{\sqrt{g}}$

$T\propto\frac{1}{\sqrt{g}}$, i.e. $\frac{T_2}{T_1}=\sqrt{\frac{g_1}{g_2}}$

where, g_1 = acceleration due to gravity on earth's surface = g g_2 = acceleration due to gravity at a height $h=R$ from earth's surface $=g/4$

[Using $g(h)=\frac{g}{\left(1+\frac{h}{R}\right)^2}$]

$$\Rightarrow\frac{T_2}{T_1}=\sqrt{\frac{g}{g/4}}=2$$

11. (c) $g=\frac{GM}{R^2}$ or $g\propto\frac{1}{R^2}$

g will increase if R decreases.

12. [2.3] Given $M_B=2M_A$

As radius is same $\Rightarrow\rho_B=2\rho_A$

Now after transfer of mass

@FAKE_CBSE_YORAI_EDUNET

$$M_A' = \rho_A \frac{4}{3}\pi\left(\frac{R^3}{8}\right) = \frac{M_A}{8}$$

and $M_B' = 2M_A + \frac{7M_A}{8} = \frac{23M_A}{8}$

Now volume of mass lost by star A = Volume added to Star B

Let R_2 be the new volume of star B.

$$\Rightarrow \frac{4}{3}\pi\left(R^3 - \left(\frac{R}{2}\right)^3\right) = \frac{4}{3}\pi(R_2^3 - R^3)$$

$$\Rightarrow R_2 = 15^{\frac{1}{3}}\frac{R}{2}$$

Now, $V \propto \sqrt{\frac{M}{R}}$

$$\Rightarrow \frac{V_B}{V_A} = \sqrt{\frac{M_B}{R_B} \times \frac{R_A}{M_A}}$$

$$= \sqrt{\frac{23M_A}{8\times 15^{\frac{1}{3}}\frac{R}{2}} \times \frac{R}{\frac{M_A}{8}\times 2}}$$

$$\Rightarrow \frac{V_B}{V_A} = \sqrt{\frac{10\times 2.3}{15^{\frac{1}{3}}}} \Rightarrow n = 2.3$$

13. $g' = g - R\omega^2\cos^2\phi$

At equator $\phi = 0$

$\therefore g' = g - R\omega^2 \Rightarrow 0 = g - R\omega^2$

$\therefore \omega = \sqrt{\frac{g}{R}} = \sqrt{\frac{9.8}{6400\times 10^3}}$

$= 1.24 \times 10^{-3}$ rad/s

14. (c) To escape a system we have to make final total energy equal to zero,

Given, $v_e = 11.2\text{km}/s = \sqrt{\frac{2GM_e}{R_e}}$

Using energy conservation,

$K_i + U_i = K_f + U_f$

$$\frac{1}{2}mv_s^2 - \frac{GM_s m}{r} - \frac{GM_e m}{R_e} = 0 + 0$$

Here, r = distance of rocket from the sun

$$\Rightarrow v_s = \sqrt{\frac{2GM_e}{R_e} + \frac{2GM_s}{r}}$$

Given, $M_s = 3\times 10^5 M_e$ and $r = 2.5\times 10^4 R$

$$v_s = \sqrt{\frac{2GM_e}{R_e} + \frac{2G\times 3\times 10^5 M_e}{2.5\times 10^4 R_e}}$$

$$= \sqrt{\frac{2GM_e}{R_e}\left(1 + \frac{3\times 10^5}{2.5\times 10^4}\right)}$$

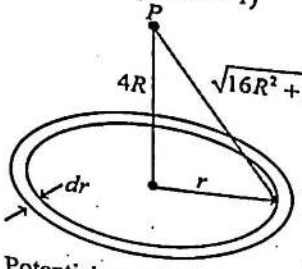
$$= \sqrt{\frac{2GM_e}{R_e}\times 13}$$

$\Rightarrow v_s = 42$ km/sec

15. (a) So, work done given by;

$W = \Delta U = U_f - U_i = U_{INFINITY} - U_p = -U_p$

$= -mV_p = -V_p$ (as $m = 1$)



Potential at point P will be obtained by integrating a small element. Assume dM be the mass of the small ring as shown

$$dM = \frac{M}{\pi(4R)^2 - \pi(3R)^2}(2\pi r)dr$$

$$= \frac{2Mr\,dr}{7R^2}$$

$$dV = -\frac{G\,dM}{\sqrt{16R^2 + r^2}}$$

$$= -\frac{2GM}{7R^2}\int_{3R}^{4R}\frac{r}{\sqrt{16R^2 + r^2}}dr$$

$$= -\frac{2GM}{7R}(4\sqrt{2} - 5)$$

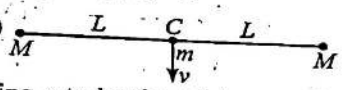
$$W = +\frac{2GM}{7R}(4\sqrt{2} - 5)$$

16. (a) $\Delta U = \frac{mgh}{1 + h/R}$

Given, $h = R$

$$\Delta U = \frac{mgR}{1 + R/R} = \frac{1}{2}mgR$$

17. (b,d)



Taking v to be the minimum velocity. According to energy conservation,

$U_c + K_c = U_\infty + K_\infty$

$$mV_c + \frac{1}{2}mv^2 = 0 + 0$$

$$v = \sqrt{-2V_C} = \sqrt{(-2)\left(-\frac{2GM}{L}\right)}$$

$$= 2\sqrt{\frac{GM}{L}}$$

This is the required answer.

18. (b,d) Given Surface area of Q is four times. So, radius of Q is two times. If Q's volume is eight times of P. Hence, mass of Q is also eight times.

Taking

$M_P = M$ and $R_P = r$

Then,

$M_Q = 8M$ and $R_Q = 2r$

Now, mass of R is $(M_P + M_Q)$ or $9M$. Hence, radius of R is $(9)^{\frac{1}{3}}r$. We know that, escape velocity from the surface of a planet is given by

$v = \sqrt{\frac{2GM}{r}}$ (r = radius of the planet)

$$v_P = \sqrt{\frac{2GM}{r}},\ v_Q = \sqrt{\frac{2G(8M)}{(2r)}}$$

$$v_R = \sqrt{\frac{2G(9M)}{(9)^{1/3}r}}$$

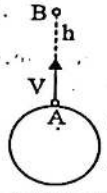
we can clearly see that,

$\frac{v_P}{v_Q} = \frac{1}{2}$ and $v_R > v_Q > v_P$.

This is the required answer.

19. (a, c, d) The gravitational field is zero at the centre of a solid sphere. The small spheres can be considered as negative mass m located at A and B. The gravitational field due to these masses at O is equal and opposite. Hence, the resultant field at O is zero. Further (c) and (d) options are correct because plane of these circles is y-z, i.e. perpendicular to X-axis i.e. potential at any point on these two circles will be equal due to the positive mass M and negative masses $-m$ and $-m$.

20. [2]



Acceleration due to gravity at height h;

$$g' = \frac{g}{\left(1 + \frac{h}{R}\right)^2} \quad ...(i)$$

Given, $g' = \frac{g}{4}$

Putting the value of g' in eqn (i) we get, $h = R$

Also, from A to B,

Loss in kinetic energy = gain in potential energy

$$\Rightarrow \frac{1}{2}mv^2 = \frac{mgh}{1 + \frac{h}{R}}$$

$$\Rightarrow \frac{v^2}{2} = \frac{gh}{1 + \frac{h}{R}} = \frac{1}{2}gR \qquad [h = R]$$

$\Rightarrow v^2 = gR$ or $v = \sqrt{gR}$

Now, $v_{esc} = \sqrt{2gR} = v\sqrt{2}$

So, $N = 2$.

© FAKE_CBSE_BY@RAJ_BOUNT

21. [3] As we know,

$$g=\frac{GM}{R^2}=\frac{G\left(\frac{4}{3}\pi R^3\right)\rho}{R^2}$$

$$\Rightarrow g\propto \rho R \Rightarrow R\propto \frac{g}{\rho}$$

Now escape velocity, $v_e=\sqrt{2gR}$

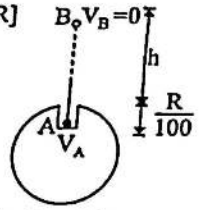
$$v_e\propto\sqrt{gR} \text{ or } v_e\propto\sqrt{g\times\frac{g}{\rho}}\propto\sqrt{\frac{g^2}{\rho}}$$

$$\frac{v_{planet}}{v_e}=\sqrt{\frac{6}{121}\times\frac{3}{2}}$$

$$\Rightarrow v_{planet}=\frac{3(11\,\text{kms}^{-1})}{11}=3\,\text{kms}^{-1}$$

where, v_{planet} is the escape velocity on the surface of planet.

22. [99R]



Speed of particle at A, v_A
= escape velocity on the surface of earth

$$=\sqrt{\frac{2GM}{R}}$$

At highest point B, $v_B=0$

Applying conservation of mechanical energy, decrease in kinetic energy = increase in gravitational potential energy

or $\frac{1}{2}mv_A^2=U_B-U_A=m(v_B-v_A)$

$$\frac{1}{2}mv_A^2=m(V_B-V_A)$$

$$\frac{1}{2}\times\frac{2GM}{R}=-\frac{GM}{R+h}$$

$$-\left(-\frac{GM}{2R^3}\left(3R^2-\left(R-\frac{R}{100}\right)^2\right)\right)$$

$$\Rightarrow \frac{1}{R}=-\frac{1}{R+h}+\frac{1}{2R}\left\{3-\left(1-\frac{1}{100}\right)^2\right\}$$

$$\Rightarrow \frac{1}{R}=-\frac{1}{R+h}+\frac{1}{2R}\left\{3-\left(1-\frac{2}{100}\right)\right\}$$

$$\{\because (1+x)^n=1+nx\}$$

$$\Rightarrow \frac{1}{R}=-\frac{1}{R+h}+\frac{1}{2R}\left\{3-\frac{98}{100}\right\}$$

$$\Rightarrow \frac{1}{R}=-\frac{1}{R+h}+\frac{1}{2R}\times\frac{202}{100}$$

$$\Rightarrow \frac{1}{R+h}=\frac{101}{100R}-\frac{1}{R}$$

$$\Rightarrow R+h=100R$$

$$\Rightarrow h=99R$$

23. We have to equate initial and final energy here

Kinetic energy required to escape $=\frac{GM_em}{R}$

Therefore, energy given to the particle $=\frac{GM_em}{2R}$

According to conservation of mechanical energy.

Kinetic energy at the surface of earth = Difference in potential energy at a height h and on the surface of earth

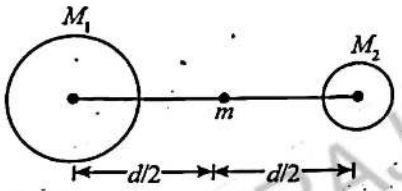
$$\frac{GM_em}{2R}=-\frac{GM_em}{(R+h)}-\left(-\frac{GM_em}{R}\right)$$

$$\frac{1}{2R}=\frac{1}{R}-\frac{1}{R+h}\Rightarrow R=h$$

24. Total mechanical energy (in the form of potential energy) of mass m at a point midway between two centres is

$$E=-\frac{GM_1m}{d/2}-\frac{GM_2m}{d/2}=-\frac{2Gm}{d}(M_1+M_2)$$

Binding energy $=\frac{2Gm}{d}(M_1+M_2)$

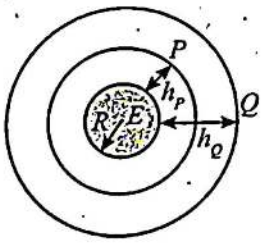


Kinetic energy required to escape the mass to infinity is,

$$\frac{1}{2}mv_e^2=\frac{2Gm}{d}(M_1+M_2)$$

$$\therefore v_e=2\sqrt{\frac{G(M_1+M_2)}{d}}$$

25. (*a*) Given, $\frac{g_P}{g_Q}=\frac{36}{25}$



$$\frac{g_P}{g_Q}=\frac{\frac{GM}{r_P^2}}{\frac{GM}{r_Q^2}}=\left(\frac{r_Q}{r_P}\right)^2$$

$$\frac{36}{25}=\left(\frac{r_Q}{r_P}\right)^2\Rightarrow \frac{r_Q}{r_P}=\frac{6}{5}$$

$$r_Q=\frac{6}{5}r_P$$

$$R+h_Q=\frac{6}{5}\left(R+\frac{R}{3}\right)$$

$$h_Q=\frac{24}{15}R-R=\frac{9}{15}R=\frac{3}{5}R$$

26. (*c*) Time period of a satellite very near to earth's surface is 84.6 min. When distance of the satellite from the surface of earth increases then Time period increases. Therefore, time period of any satellite orbiting a few 100 km above the earth's surface have to be slightly larger than 84.6 as its distance from earth is large.

Therefore, the most appropriate option is (*c*) or $2h$.

27. (*a*) Force exerted on satellite is always towards earth, hence, acceleration of satellite S is always in the direction towards centre of the earth.

Total torque of gravitational force is about the centre of earth is zero.

Hence, angular momentum (both in magnitude and direction) of S around the centre of earth is constant or conserved throughout.

Since, the force F is conservative in nature, So, the mechanical energy of the satellite remains the same.

Speed of S is maximum when it is nearer to earth and minimum when it is farthest.

Therefore, the first option is correct.

28. (*b*) $\frac{mv^2}{R}\propto R^{-5/2}$

$\therefore v\propto R^{-3/4}$

Now, $T=\frac{2\pi R}{v}$ or $T^2\propto\left(\frac{R}{v}\right)^2$

or $T^2\propto\left(\frac{R}{R^{-3/4}}\right)^2$ or $T^2\propto R^{7/2}$

29. (*b*) We, $v=\sqrt{\frac{GM}{R}}$

Assume $R_1=R$, then $R_2=4R$

If $m_2=m$, then $m_1=2m$

List-I

P. $\frac{v_1}{v_2}=\sqrt{\frac{R_2}{R_1}}=\sqrt{\frac{4R}{R}}=2:1$

Q. $L=mvR$

$$\Rightarrow \frac{L_1}{L_2}=\frac{R(2m)v_1}{4R(m)v_2}=\frac{1}{2}(2)=1:1$$

R. $\frac{K_1}{K_2}=\frac{\frac{1}{2}(2m)v_1^2}{\frac{1}{2}(m)v_2^2}=2(4)=8:1$

S. $\frac{T_1}{T_2}=\left(\frac{R_1}{R_2}\right)^{3/2}=\left(\frac{1}{4}\right)^{3/2}=1:8$

@FAKE_CBSE_X@PAJEEDIRECT

$\because T \propto r^{3/2}$

$$\therefore \frac{T_2}{T_1} = \left(\frac{r_2}{r_1}\right)^{3/2}$$

$$\text{or } T_2 = \left(\frac{r_2}{r_1}\right)^{3/2} T_1$$

$$T_2 = \left(\frac{3.5R}{7R}\right)^{3/2} (24)\text{h} = 8.48 \text{ h}$$

($T_1 = 24$ h for geostationary satellite)

31. [False] New Delhi is not on the equatorial plane.

32. $T \propto r^{3/2}$ or $r \propto T^{2/3}$

$$\Rightarrow \frac{r_2}{r_1} = \left(\frac{T_2}{T_1}\right)^{2/3}$$

$$r_2 = \left(\frac{T_2}{T_1}\right)^{2/3} r_1 = \left(\frac{8}{1}\right)^{2/3} (10^4)$$

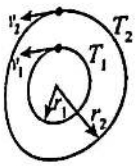
$= 4 \times 10^4$ km

Now, $v_1 = \frac{2\pi r_1}{T_1} = \frac{(2\pi)(10^4)}{1}$

$= 2\pi \times 10^4$ km/h

$$v_2 = \frac{2\pi r_2}{T_2} = \frac{(2\pi)(4\times10^4)}{8}$$

$= (\pi \times 10^4)$ km/h



(a) Speed of S_2 relative to $S_1 = v_2 - v_1$

$= -\pi \times 10^4$ km/h

(b) Angular speed of S_2 as observed by S_1

$$\omega_r = \frac{|v_2 - v_1|}{|r_2 - r_1|} = \frac{\left(\pi\times10^4 \times \frac{5}{18} m/s\right)}{(3\times10^7\, m)}$$

$= 0.3 \times 10^{-3}$ rad/s

$= 3.0 \times 10^{-4}$ rad/s

33. (a) Orbital speed of a satellite at distance r from centre of earth,

$$v_o = \sqrt{\frac{GM}{r}} = \sqrt{\frac{GM}{R+h}} \quad \ldots(i)$$

Given,

$$v_o = \frac{v_e}{2} = \frac{\sqrt{2GM/R}}{2} = \sqrt{\frac{GM}{2R}} \quad \ldots(ii)$$

From Eqs. (i) and (ii), we get

$h = R = 6400$ km

(b) Decrease in potential energy = increase in kinetic energy

or $\frac{1}{2}mv^2 = \Delta U$

$$\therefore v = \sqrt{\frac{2(\Delta U)}{m}} = \sqrt{\frac{2\left(\frac{mgh}{1+h/R}\right)}{m}}$$

$$= \sqrt{gR} = \sqrt{9.8\times6400\times10^3}$$

$= 7919$ m/s $= 7.9$ km/s

34. (d) For binary star system, angular velocity and time period of both the stars are equal. As both stars are moving due to force by one on another.

35. (b) As Kepler's law give relation between time and distance so we use Kepler's law here,

From Kepler's third law

$T^2 \propto r^3$ or $T \propto (r)^{3/2}$

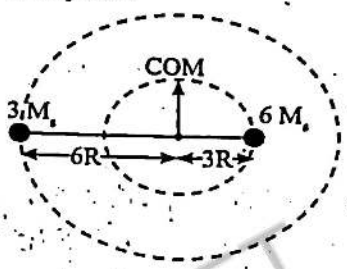
$$T_2 = T_1\left(\frac{r_2}{r_1}\right)^{\frac{3}{2}} = 365\left(\frac{1}{2}\right)^{\frac{3}{2}}$$

$T_2 = 129$ days $\Rightarrow T_2 \approx 129$ day

36. [9] Circular orbits

$$T = 2\pi\sqrt{\frac{R^3}{GM_s}}$$

Binary stars



For mass $3M_s$:

$$\frac{G\times3M_s\times M_s}{(9R)^2} = \frac{3M_sV^2}{6R}$$

$$\Rightarrow V^2 = \frac{4}{9}\frac{GM_s}{R}$$

$$\therefore T' = \frac{2\pi r'}{V} = \frac{2\pi\times6R\times3}{2}\sqrt{\frac{R}{GM_s}}$$

$$= 2\pi \times 9 \times \sqrt{\frac{R^3}{GM_s}} = 9T.$$

37. $\frac{dA}{dt} = \frac{L}{2m}$ = constant, because angular momentum of planet (L) about the centre of sun is constant. Thus, this law comes from law of conservation of angular momentum.

@FAKE_CBSE_@RAJ_EDUNET

10 Mechanical Properties of Solids

Scan for Sol.

JEE-Main

T1 Strain, Stress, Young's Modulus of Elasticity

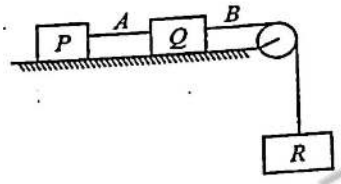
1. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R) **[27 Jan, 2024 (Shift-II)]**
Assertion (A): The property of body, by virtue of which it tends to regain its original shape when the external force is removed, is Elasticity.
Reason (R): The restoring force depends upon the bonded inter atomic and inter molecular force of solid.
In the light of the above statements; choose the correct answer from the options given below:
(*a*) (A) is false but (R) is true
(*b*) (A) is true but (R) is false
(*c*) Both (A) and (R) are true and (R) is the correct explanation (A)
(*d*) Both (A) and (R) are true but (R) is not the correct explanation of (A)

2. A wire of length L and radius r is clamped at one end. If its other end is pulled by a force F, its length increases by l. If the radius of the wire and the applied force both are reduced to half of their original values keeping original length constant, the increase in length will become. **[29 Jan, 2024 (Shift-II)]**
(*a*) 3 times (*b*) 3/2 times (*c*) 4 times (*d*) 2 times

3. Two metallic wires P and Q have same volume and are made up of same material. If their area of cross sections are in the ratio 4 : 1 and force F_1 is applied to P, an extension of Δl is produced. The force which is required to produce same extension in Q is F_2.
[29 Jan, 2024 (Shift-II)]
The value of $\frac{F_1}{F_2}$ is: _____.

4. Young's modules of material of a wire of length '*L*' and cross-sectional area *A* is *Y*. If the length of the wire is doubled and cross-sectional area is halved then Young's modules will be:
[30 Jan, 2024 (Shift-I)]
(*a*) $\frac{Y}{4}$ (*b*) $4Y$ (*c*) Y (*d*) $2Y$

5. Each of three blocks *P*, *Q* and *R* shown in figure has a mass of 3 kg. Each of the wire *A* and *B* has cross-sectional area 0.005 cm^2 and Young's modulus 2×10^{11} N m^{-2}. Neglecting friction, the longitudinal strain on wire *B* is _____ $\times 10^{-4}$.
(Take $g = 10$ m/s^2) **[30 Jan, 2024 (Shift-I)]**



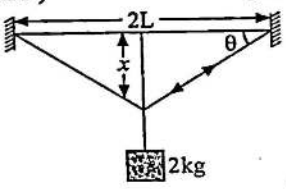
6. A solid circular disc of mass 50 kg rolls along a horizontal floor so that its center of mass has a speed of 0.4 m/s. The absolute value of work done on the disc to stop it is _____ J.
[31 Jan, 2024 (Shift-I)]

7. One end of a metal wire is fixed to a ceiling and a load of 2 kg hangs from the other end. A similar wire is attached to the bottom of the load and another load of 1 kg hangs from this lower wire. Then the ratio of longitudinal strain of upper wire to that of the lower wire will be ___.
[Area of cross section of wire 0.005 cm^2, $Y = 2 \times 10^{11}$ Nm^{-2} and $g = 10$ ms^{-2}] **[1 Feb, 2024 (Shift-II)]**

8. An elastic spring under tension of 3 *N* has a length *a*. Its length is l under tension 2 *N*. For its length $(3a - 2b)$, the value of tension will be _____ *N*. **[04 April, 2024 (Shift-I)]**

9. The density and breaking stress of a wire are 6×10^4 kg/m^3 and 1.2 $\times 10^8$ N/m^2 respectively. The wire is suspended from a rigid support on a planet where acceleration due to gravity is $1^{rd}/3$ of the value on the surface of earth. The maximum length of the wire with breaking is _____ *m* (take, $g = 10$ m/s^2) **[05 April, 2024 (Shift-I)]**

10. A wire of cross sectional area *A*, modulus of elasticity 2×10^{11} Nm^{-2} and length 2 m is stretched between two vertical rigid supports. When a mass of 2 kg is suspended at the middle it sags lower from its original position making angle $\theta = 1/100$ radian on the points of support. The value of *A* is _____ $\times 10^{-4}$ m^2 (consider $x << L$).
(given : $g = 10$ m/s^2) **[06 April, 2024 (Shift-I)]**



11. Two persons pull a wire towards themselves. Each person exerts a force of 200 N on the wire. Young's modulus of the material of wire is 1×10^{11} N m^{-2}. Original length of the wire is 2 m and the area of cross section is 2 cm^2. The wire will extend in length by _____ μm. **[09 April, 2024 (Shift-I)]**

@MAKE YOUR CAREER EDUJET

12. A 100 m long wire having cross-sectional area $6.25 \times 10^{-4} m^2$ and Young's modulus is $10^{10}\ Nm^{-2}$ is subjected to a load of 250 N, then the elongation in the wire will be: **[24 Jan, 2023 (Shift-I)]**

(a) 6.25×10^{-3} m (b) 4×10^{-4} m

(c) 6.25×10^{-6} m (d) 4×10^{-3} m

13. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R

Assertion A: Steel is used in the construction of buildings and bridges.

Reason R: Steel is more elastic and its elastic limit is high.

In the light of above statements, choose the most appropriate answer from the options given below **[24 Jan, 2023 (Shift-II)]**

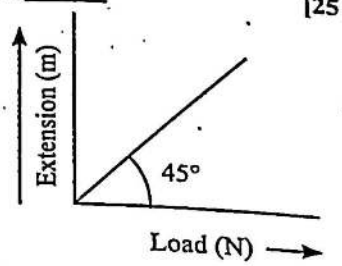
(a) Both A and R are correct but R is NOT the correct explanation of A

(b) A is not correct but R is correct

(c) Both A and R are correct and R is the correct explanation of A

(d) A is correct but R is not correct

14. As shown in the figure, in an experiment to determine Young's modulus of a wire, the extension-load curve is plotted. The curve is a straight line passing through the origin and makes an angle of 45° with the load axis. The length of the wire is 62.8 cm and its diameter is 4 mm. The Young's modulus is found to be $x \times 10^4\ Nm^{-2}$. The value of x is_____ **[25 Jan, 2023 (Shift-I)]**



15. A force is applied to a steel wire 'A', rigidly clamped at one end. As a result elongation in the wire is 0.2 mm. If same force is applied to another steel wire 'B' of double the length and a diameter 2.4 times that of the wire 'A', the elongation in the wire 'B' will be (wires having uniform circular cross sections) **[30 Jan, 2023 (Shift-II)]**

(a) 6.06×10^{-2} mm (b) 2.77×10^{-2} mm

(c) 3.0×10^{-2} mm (d) 6.9×10^{-2} mm

16. Under the same load, wire A having length 5.0 m and cross section $2.5 \times 10^{-5}\ m^2$ stretches uniformly by the same amount as another wire B of length 6.0 m and a cross section of $3.0 \times 10^{-5}\ m^2$ stretches. The ratio of the Young's modulus of wire A to that of wire B will be: **[31 Jan, 2023 (Shift-II)]**

(a) 1 : 4 (b) 1 : 1 (c) 1 : 10 (d) 1 : 2

17. The Young's modulus of a steel wire of length 6 m and cross-sectional area 3 mm^2, is $2 \times 11^{11}\ N/m^2$. The wire is suspended from its support on a given planet. A block of mass 4 kg is attached to the free end of the wire. The acceleration due to gravity on the planet is $\frac{1}{4}$ of its value on the earth. The elongation of wire is (Take g on the earth = 10 m/s^2) **[1 Feb, 2023 (Shift-II)]**

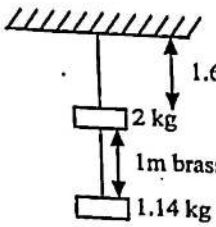
(a) 1 cm (b) 1 mm (c) 0.1 mm (d) 0.1 cm

18. A steel rod has a radius of 20 mm and a length of 20m. A force of 62.8 kN stretches it along its length. Young's modulus of steel is $2.0 \times 10^{11}\ N/m^2$. The longitudinal strain produced in the wire is ____ $\times 10^{-5}$ **[06 April, 2023 (Shift-I)]**

19. A metal block of mass m is suspended from a rigid support through a metal wire of diameter 14 mm. The tensile stress developed in the wire under equilibrium state is $7 \times 10^3\ Nm^{-2}$. The value of mass m is _____ kg.

(Take, $g = 9.8\ ms^{-2}$ and $\pi = \frac{22}{7}$) **[6 April, 2023 (Shift-II)]**

20. Two wires, each of radius 0.2 cm and negligible mass, one made of steel and other made of brass are loaded as shown in the figure. The elongation of the steel wire is ____ $\times 10^{-6}$ m. [Young's modulus for steel = $2 \times 10^{11}\ Nm^{-2}$ and $g = 10\ ms^{-2}$] **[10 April, 2023 (Shift-I)]**



21. Young's moduli of the material of wires A and B are in the ratio of 1 : 4, while its area of cross sections are in the ratio of 1 : 3. If the same amount of load is applied to both the wires, the amount of elongation produced in the wires A and B will be in the ratio of [Assume length of wires A and B are same] **[10 April, 2023 (Shift-II)]**

(a) 36 : 1 (b) 12 : 1 (c) 1 : 36 (d) 1 : 12

22. The length of wire becomes l_1 and l_2 when 100 N and 120 N tensions are applied respectively. If $10\,l_2 = 11\,l_1$, the natural length of wire will be $\frac{1}{x} l_1$. Here the value of x is _____. **[11 April, 2023 (Shift-I)]**

23. A wire of length 'L' and radius 'r' is clamped rigidly at one end. When the other end of the wire is pulled by a force f, its length increases by 'ℓ'. Another wire of same material of length '$2L$' and radius '$2r$' is pulled by a force '$2f$' Then the increase in its length will be : **[15 April, 2023 (Shift-I)]**

(a) 2ℓ (b) ℓ (c) 4ℓ (d) $\ell/2$

24. The elongation of a wire on the surface of the earth is 10^{-4} m. The same wire of same dimensions is elongated by 6×10^{-5} m on another planet. The acceleration due to gravity on the planet will be _____ ms^{-2}. (Take acceleration due to gravity on the surface of earth = 10 ms^{-2}) **[26 June, 2022 (Shift-I)]**

25. A wire of length L is hanging from a fixed support. The length changes to L_1 and L_2 when masses 1kg and 2kg are suspended respectively from its free end. Then the value of L is equal to: **[29 June, 2022 (Shift-I)]**

(a) $\sqrt{L_1 L_2}$ (b) $\frac{L_1 + L_2}{2}$

(c) $2L_1 - L_2$ (d) $3L_1 - 2L_2$

26. A wire of length L and radius r is clamped rigidly at one end. When the other end of the wire is pulled by a force F, its length increases by 5cm. Another wire of the same material of length $4L$ and radius $4r$ pulled by a force $4F$ under same conditions. The increase in length of this wire is _____ cm. **[25 July, 2022 (Shift-I)]**

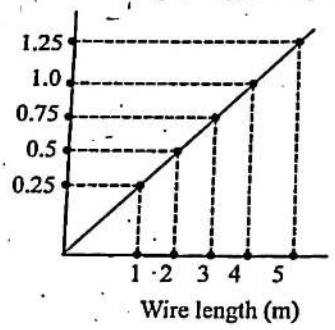
@MKDEEX@RAJEEVNET

27. A uniform heavy rod of mass 20 kg, cross sectional area 0.4 m^2 and length 20 m is hanging from a fixed support. Neglecting the lateral contraction, the elongation in the rod due to its own weight is $x \times 10^{-9}$ m. The value of x is _____: (Given. Young's modulus $Y = 2 \times 10^{11}$ Nm^{-2} and $g = 10$ ms^{-2}) **[26 July, 2022 (Shift-II)]**

28. The area of cross section of the rope used to lift a load by a crane is 2.5×10^{-4} m^2. The maximum lifting capacity of the crane is 10 metric tons. To increase the lifting capacity of the crane to 25 metric tons, the required area of cross section of the rope should be: (take $g = 10$ ms^{-2}) **[26 July, 2022 (Shift-II)]**

(a) 6.25×10^{-4} m^2 (b) 10×10^{-4} m^2
(c) 1×10^{-4} m^2 (d) 1.67×10^{-4} m^2

29. In an experiment to determine the Young's modulus, steel wires of five different lengths (1, 2, 3, 4, and 5m) but of same cross section (2 mm^2) were taken and curves between extension and load were obtained. The slope (extension / load) of the curves were plotted with the wire length and the following graph is obtained. If the Young's modulus of given steel wires is $x \times 10^{11}$ Nm^{-2}, then the value of x is _____. **[27 July, 2022 (Shift-II)]**



30. The force required to stretch a wire of cross-section 1 cm^2 to double its length will be: (Given Young's modulus of the wire = 2×10^{11} N/m^2) **[28 July, 2022 (Shift-I)]**

(a) 1×10^7 N (b) 1.5×10^7 N (c) 2×10^7 N (d) 2.5×10^7 N

31. A string of area of cross – section 4 mm^2 and length 0.5 m is connected with a rigid body of mass 2 kg. The body is rotated in a vertical circular path of radius 0.5 m. The body acquires a speed of 5 m/s at the bottom of the circular path. Strain produced in the string when the body is at bottom of the circle is _____ $\times 10^{-5}$.

(use Young's modulus 10^{11} N /m^2 and $g = 10$ m/s^2) **[28 July, 2022 (Shift-II)]**

32. If the length of a wire is made double and radius is halved of its respective values. Then, the Young's modulus of the material of wire will: **[29 July, 2022 (Shift-I)]**

(A) remain same
(B) become 8 times its initial value
(C) become $\frac{1}{4}^{th}$ of its initial value
(D) become 4 times its initial value

(a) 2×10^{-9} m (b) 5×10^{-10} m
(c) 4×10^{-8} m (d) 5×10^{-8} m

33. If Y, K and η are the value of Young's moduls, bulk modulus of rigidity of any material respectively. Choose the correct relation for these parameters **[24 Feb, 2021 (Shift-I)]**

(a) $Y = \frac{9K\eta}{2\eta + 3K}$ N/m^2 (b) $K = \frac{Y\eta}{9\eta - 3Y}$ N/m^2

(c) $\eta = \frac{3YK}{9K + Y}$ N/m^2 (d) $Y = \frac{9K\eta}{3K - \eta}$ N/m^2

34. A uniform metallic wire is elongated by 0.04 m when subjected to a linear force F. The elongation, if its length and diameter is doubled and subjected to the same force will be _____ cm. **[24 Feb, 2021 (Shift-II)]**

35. The length of metallic wire is ℓ_1 when tension in it is T_1. It is ℓ_2 when the tension is T_2. The original length of the wire will be: **[26 Feb, 2021 (Shift-II)]**

(a) $\frac{T_2\ell_1 + T_1\ell_2}{T_1 + T_2}$ (b) $\frac{T_1\ell_1 - T_2\ell_2}{T_2 - T_1}$
(c) $\frac{T_2\ell_1 - T_1\ell_2}{T_2 - T_1}$ (d) $\frac{\ell_1 + \ell_2}{2}$

36. Two separate wires A and B are stretched by 2 mm and 4 mm respectively, when they are subjected to a force of 2N. Assume that both the wires are made up of same material and the radius of wire B is 4 times that of the radius of wire A. The length of the wires A and B are in the ratio of $a : b$. Then a/b can be expressed as $\frac{1}{x}$ where x is _____. **[18 March, 2021 (Shift-I)]**

37. The value of tension in a long thin metal wire has been changed from T_1 to T_2. The lengths of the metal wire at two different values of tension T_1 and T_2 are ℓ_1 and ℓ_2 respectively. The actual length of the metal wire is: **[20 July, 2021 (Shift-I)]**

(a) $\frac{T_1\ell_2 - T_2\ell_1}{T_1 - T_2}$ (b) $\sqrt{T_1T_2\ell_1\ell_2}$
(c) $\frac{\ell_1 + \ell_2}{2}$ (d) $\frac{T_1\ell_1 - T_2\ell_2}{T_1 - T_2}$

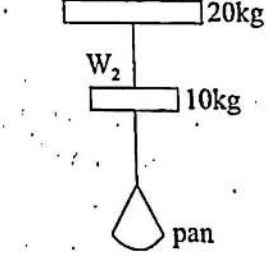
38. The length of a metal wire is ℓ_1, when the tension in it is T_1 and is ℓ_2 when the tension is T_2. The natural length of the wire is: **[20 July, 2021 (Shift-II)]**

(a) $\sqrt{\ell_1\ell_2}$ (b) $\frac{\ell_1 + \ell_2}{2}$
(c) $\frac{\ell_1T_2 - \ell_2T_1}{T_2 - T_1}$ (d) $\frac{\ell_1T_2 + \ell_2T_1}{T_2 + T_1}$

39. Two wires of same length and radius are joined end to end and loaded. The Young's modulii of the materials of the two wires are Y_1 and Y_2. The combination behaves as a single wire then its Young's modulus is: **[25 July, 2021 (Shift-I)]**

(a) $Y = \frac{Y_1Y_2}{2(Y_1 + Y_2)}$ (b) $Y = \frac{2Y_1Y_2}{3(Y_1 + Y_2)}$
(c) $Y = \frac{Y_1Y_2}{Y_1 + Y_2}$ (d) $Y = \frac{2Y_1Y_2}{Y_1 + Y_2}$

40. Wires W_1 and W_2 are made of same material having the breaking stress of 1.25×10^9 N /m^2. W_1 and W_2 have cross-sectional area of 8×10^{-7} m^2 and 4×10^{-7} m^2, respectively. Masses of 20 kg and 10 kg hang from them as shown in the figure. The maximum mass that can be placed in the pan without breaking the wires is _____ kg. (Use $g = 10$ m/s^2) **[27 Aug, 2021 (Shift-II)]**



@FAKE_CBSE_@RJ_EDUNET

41. A uniform heavy rod of weight 10 kg ms^{-2}, cross-sectional area 100 cm^2 and length 20 cm is hanging from a fixed support. Young modulus of the material of the rod is 2×10^{11} Nm^{-2}. Neglecting the lateral contraction, find the elongation of rod due to its own weight:
[31 Aug, 2021 (Shift-I)]

42. Four identical hollow cylindrical columns of mild steel support a big structure of mass 50×10^3 kg, The inner and outer radii of each column are 50 cm and 100 cm respectively. Assuming uniform local distribution, calculate the compression strain of each column.
[31 Aug, 2021 (Shift-II)]
[Use $Y = 2.0 \times 10^{11}$ Pa, $g = 9.8$ m/s^2]
(a) 3.60×10^{-8} (b) 2.60×10^{-7}
(c) 1.87×10^{-3} (d) 7.07×10^{-4}

43. Speed of a transverse wave on a straight wire (mass 6.0 g, length 60 cm and area of cross- section 1.0 mm^2) is 90 ms^{-1}. If the young's modulus of wire is 16×10^{11} Nm^{-2}, the extension of wire over its natural length is:
[7 Jan, 2020 (Shift-I)]
(a) 0.03 mm (b) 0.01 mm
(c) 0.02 mm (d) 0.04 mm

44. A rod of length L at room temperature and uniform area of cross section A, is made of a metal having coefficient of linear expansion α/°C. It is observed that an external compressive force F, is applied on each of its ends, prevents any change in the length of the rod, when it temperature rises by ΔT K. Young's modulus, Y, for this metal is:
[9 Jan, 2019 (Shift-I)]
(a) $\frac{F}{A\alpha\Delta T}$ (b) $\frac{F}{A\alpha(\Delta T - 273)}$
(c) $\frac{F}{2A\alpha\Delta T}$ (d) $\frac{2F}{A\alpha\Delta T}$

45. A load of mass M kg is suspended from a steel wire of length 2 m and radius 1.0 mm in Searle's apparatus experiment. The increase in length produced in the wire is 4.0 mm. Now the load is fully immersed in a liquid of relative density 2. The relative density of the material of load is 8. The new value of increase in length of the steel wire is:
[12 Jan, 2019 (Shift-II)]
(a) 3.0 mm (b) 4.0 mm (c) 5.0 mm (d) zero

46. A steel wire having a radius of 2.0 mm, carrying a load of 4 kg, is hanging from a ceiling. Given that $g = 3.1\ \pi$ ms^{-2}, what will be the tensile stress that would be developed in the wire?
[8 April, 2019 (Shift-I)]
(a) 4.8×10^6 Nm^{-2} (b) 5.2×10^6 Nm^{-2}
(c) 6.2×10^6 Nm^{-2} (d) 3.1×10^6 Nm^{-2}

47. Young's moduli of two wires A and B in the ratio 7 : 4. Wire A is 2 m long and has radius R. Wire B is 1.5 m long and has radius 2 mm. If the two wires stretch by the same length for a given load, then the value of R is close to
[8 April, 2019 (Shift-II)]
(a) 1.9 mm (b) 1.7 mm
(c) 1.5 mm (d) 1.3 mm

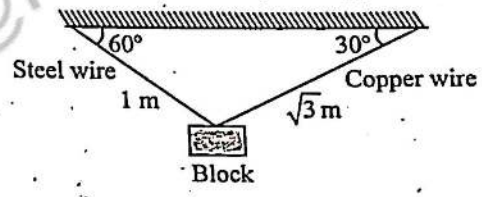
48. A boy's catapult is made of rubber cord which is 42 cm long, with 6 mm diameter of cross-section and of negligible mass. The boy keeps a stone weighing 0.02 kg on it and stretches the cord by 20 cm by applying a constant force. When released, the stone flies off with a velocity of 20 ms^{-1}. Neglect the change in the area of cross-section of the cord while stretched. The Young's modulus of rubber is closest to:
[8 April, 2019 (Shift-I)]
(a) 10^4 Nm^{-2} (b) 10^8 Nm^{-2}
(c) 10^6 Nm^{-2} (d) 10^3 Nm^{-2}

49. In an experiment, brass and steel wires of length 1 m each with areas of cross section 1 mm^2 are used. The wires are connected in series and one end of the combined wire is connected to a rigid support and other end is subjected to elongation. The stress required to produce a net elongation of 0.2 mm is:
[10 April, 2019 (Shift-II)]
(Given, the Young's Modulus for steel and brass are respectively, 120×10^9 N/m^2 and 60×10^9 N/m^2)
(a) 0.2×10^6 N/m^2 (b) 4.0×10^6 N/m^2
(c) 1.8×10^6 N/m^2 (d) 1.2×10^6 N/m^2

50. The elastic limit of brass is 379 MPa. What should be the minimum diameter of a brass rod if it is to support a 400 N load without exceeding its elastic limit?
[10 April, 2019 (Shift-II)]
(a) 1.16 mm (b) 0.90 mm (c) 1.36 mm (d) 1.00 mm

51. A uniform cylindrical rod of length L and radius r, is made from a material whose Young's modulus of Elasticity equals Y. When this rod is heated by temperature T and simultaneously subjected to a net longitudinal compressional force F, its length remains unchanged. The coefficient of volume expansion, of the material of the rod, is (nearly) equals to:
[12 April, 2019 (Shift-II)]
(a) $9F/(\pi r^2 YT)$ (b) $F/(3\pi r^2 YT)$
(c) $3F/(\pi r^2 YT)$ (d) $6F/(\pi r^2 YT)$

52. A block of weight 100 N is suspended by copper and steel wires of same cross sectional area 0.5 cm^2 and, length $\sqrt{3}$ m and 1 m, respectively. Their other ends are fixed on a ceiling as shown in figure. The angles subtended by copper and steel wires with ceiling are 30° and 60°, respectively. If elongation in copper wire is (Δl_c) and elongation in steel wire is (Δl_s), then the ratio $\frac{\Delta \ell_c}{\Delta \ell_s}$ is _____. [Young's modulus for copper and steel are 1×10^{11} N/m^2 and 2×10^{11} N/m^2 respectively] **[JEE Adv, 2019]**



T2 Bulk Modulus, Shear Modulus, Elasticity Potential Energy

53. Match List-I with List-II:

	List-I		List-II
(A)	A force that restores an elastic body of unit area to its original state	(I)	Bulk modulus
(B)	Two equal and opposite forces parallel to opposite faces	(II)	Young's modulus
(C)	Forces perpendicular everywhere to the surface per unit area same everywhere	(III)	Stress
(D)	Two equal and opposite forces perpendicular to opposite faces	(IV)	Shear modulus

@FAKE_BOOK @RAJ_DIXIT

Choose the correct answer from the options given below:

[05 April, 2024 (Shift-II)]

(a) (A)-(II), (B)-(IV), (C)-(I), (D)-(III)
(b) (A)-(IV), (B)-(II), (C)-(III), (D)-(I)
(c) (A)-(III), (B)-(IV), (C)-(I), (D)-(II)
(d) (A)-(III), (B)-(I), (C)-(II), (D)-(IV)

54. Choose the correct relationship between Poisson ratio (σ), bulk modulus (K) and modulus of rigidity (η) of a given solid object:

[30 Jan, 2023 (Shift-I)]

(a) $\sigma = \frac{3K-2\eta}{6K+2\eta}$ (b) $\sigma = \frac{6K+2\eta}{3K-2\eta}$

(c) $\sigma = \frac{3K+2\eta}{6K+2\eta}$ (d) $\sigma = \frac{6K-2\eta}{3K-2\eta}$

55. A certain pressure 'P' is applied to 1 litre of water and 2 litre of a liquid separately. Water gets compressed to 0.01% whereas the liquid gets compressed to 0.03%. The ratio of Bulk modulus of water to that of the liquid is $\frac{3}{x}$. The value of x is_____.

[01 Feb 2023 (Shift-I)]

56. An aluminium rod with Young's modulus $Y = 7.0 \times 10^{10}\ N/m^2$ undergoes elastic strain of 0.04%. The energy per unit volume stored in the rod in SI unit is:

[8 April, 2023 (Shift-I)]

(a) 5600 (b) 8400 (c) 2800 (d) 11200

57. The elastic potential energy stored in a steel wire of length 20 m stretched through 2 cm is 80 J. The cross sectional area of the wire is _____ mm².

(Given, $y = 2.0 \times 10^{11}\ Nm^{-2}$)

[13 April, 2023 (Shift-I)]

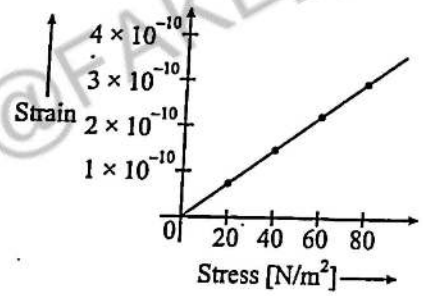
58. The bulk modulus of a liquid is $3 \times 10^{10} Nm^{-2}$. The pressure required to reduce the volume of liquid by 2% is:

[24 June, 2022 (Shift-I)]

(a) $3 \times 10^8\ Nm^{-2}$ (b) $9 \times 10^8\ Nm^{-2}$
(c) $6 \times 10^8\ Nm^{-2}$ (d) $12 \times 10^8\ Nm^{-2}$

59. The elastic behaviour of material for linear stress and linear strain, is shown in the figure. The energy density for a linear strain of 5×10^{-4} is _____ kJ/m³. Assume that material is elastic upto the linear strain of 5×10^{-4}.

[26 June, 2022 (Shift-I)]



60. A square aluminium (shear modulus is $25 \times 10^9 Nm^{-2}$) slab of side 60 cm and thickness 15 cm is subjected to a shearing force (on its narrow face) of $18.0 \times 10^4\ N$. The lower edge is riveted to the floor. The displacement of the upper edge is _____ μm.

[27 July, 2022 (Shift-I)]

61. The normal density of a material its ρ and its bulk modulus of elasticity is K. The magnitude of increase in density of material when a pressure P is applied uniformly on all sides, will be :

[26 Feb, 2021 (Shift-I)]

(a) $\frac{K}{\rho P}$ (b) $\frac{PK}{\rho}$

(c) $\frac{\rho K}{P}$ (d) $\frac{\rho P}{K}$

62. An object is located at 2 km beneath the surface of the water. If the fractional compression $\frac{\Delta V}{V}$ is 1.36%, the ratio of hydraulic stress to the corresponding hydraulic strain will be [Given, density of water is $1000 kgm^{-3}$ and $g = 9.8\ ms^{-2}$.]

[17 March, 2021 (Shift-II)]

(a) $1.44 \times 10^7\ Nm^{-2}$ (b) $1.96\ 10^7\ Nm^{-2}$
(c) $2.26 \times 10^9\ Nm^{-2}$ (d) $1.44 \times 10^9\ Nm^{-2}$

63. A stone of mass 20 g is projected from a rubber catapult of length 0.1 m and area of cross section $10^{-6}\ m^2$ stretched by an amount 0.04 m. The velocity of the projected stone is _____ m/s. (Young's modulus of rubber = $0.5 \times 10^9\ N/m^2$)

[27 July, 2021 (Shift-I)]

64. When a rubber ball is taken to a depth of _____ m in deep sea, its volume decreases by 0.5%. (The bulk modulus of rubber = $9.8 \times 10^8\ Nm^{-2}$ and Density of sea water = $10^3\ kgm^{-3}$, $g = 9.8\ m/s^2$)

[31 Aug, 2021 (Shift-I)]

65. Two steel wires having same length are suspended from a ceiling under the same load. If the ratio of their energy stored per unit volume is 1 : 4, the ratio of their diameters is:

[9 Jan, 2020 (Shift-II)]

(a) 1 : 2 (b) $1 : \sqrt{2}$
(c) 2 : 1 (d) $\sqrt{2} : 1$

66. A cube of metal is subjected to a hydrostatic pressure of 4 GPa. The percentage change in the length of the side of the cube is close to (Given bulk modulus of metal, $B = 8 \times 10^{10}$ Pa)

[4 Sep, 2020 (Shift-II)]

(a) 0.6 (b) 20 (c) 1.67 (d) 5

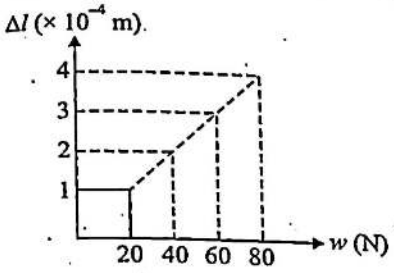
@FAKE_JOKE_X@TRUEDUNET

"Elastic Behaviour, Longitudinal Stress, Young Modulus"

Single Correct

1. One end of a horizontal thick copper wire of length $2L$ and radius $2R$ is welded to an end of another horizontal thin copper wire of length L and radius R. When the arrangement is stretched by applying forces at two ends, the ratio of the elongation in the thin wire to that in the thick wire is C-48.69 W-48.19 UA-3.12 (JEE Adv. 2013)
(a) 0.25 (b) 0.50 (c) 2.00 (d) 4.00

2. The adjacent graph shows the extension (Δl) of a wire of length 1m suspended from the top of a roof at one end and with a load w connected to the other end. If the cross-sectional area of the wire is 10^{-6} m², calculate from the graph the Young's modulus of the material of the wire. (JEE Adv. 2003)



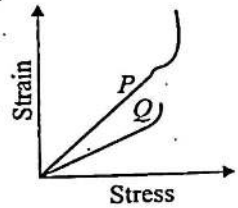
(a) 2×10^{11} N/m² (b) 2×10^{-11} N/m²
(c) 3×10^{12} N/m² (d) 2×10^{13} N/m²

3. Two rods of different materials having coefficients of thermal expansion α_1, α_2 and Young's moduli Y_1, Y_2 respectively are fixed between two rigid massive walls. The rods are heated such that they undergo the same increase in temperature. There is no bending of the rods. If $\alpha_1 : \alpha_2 = 2:3$, the thermal stresses developed in the two rods are equal provided $Y_1 : Y_2$ is equal to (IIT-JEE 1989)
(a) 2:3 (b) 1:1 (c) 3:2 (d) 4:9

4. The following four wires are made of the same material. Which of these will have the largest extension when the same tension is applied? (IIT-JEE 1981)
(a) Length = 50 cm, diameter = 0.5 mm
(b) Length = 100 cm, diameter = 1 mm
(c) Length = 200 cm, diameter = 2 mm
(d) Length = 300 cm, diameter = 3 mm

Multiple Correct

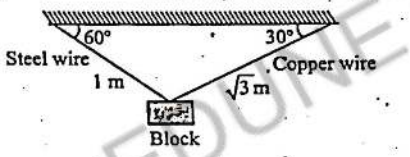
5. In plotting stress versus strain curves for two materials P and Q, a student by mistake puts strain on the Y-axis and stress on the X-axis as shown in the figure. Then the correct statement is/are (JEE Adv. 2015)



(a) P has more tensile strength than Q
(b) P is more ductile than Q
(c) P is more brittle than Q
(d) The Young's modulus of P is more than that of Q

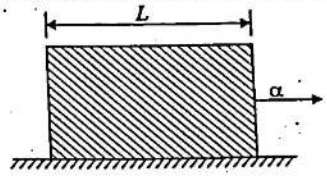
Numerical Types/Integer Types

6. A block of weight 100 N is suspended by copper and steel wires of same cross sectional area 0.5 cm² and, length $\sqrt{3}$ m and 1 m, respectively. Their other ends are fixed on a ceiling as shown in figure. The angles subtended by copper and steel wires with ceiling are 30° and 60°, respectively. If elongation in copper wire is (Δl_C) and elongation in steel wire is (Δl_S), then the ratio $\frac{\Delta \ell_C}{\Delta \ell_S}$ is _____. [Young's modulus for copper and steel are 1×10^{11} N/m² and 2×10^{11} N/m² respectively]
C-34 W-48 UA-18 (JEE Adv. 2019)



Subjective

7. A uniform rod of length L and density ρ is being pulled along a smooth floor with a horizontal acceleration α (see figure).



The magnitude of the stress at the transverse cross-section through the mid-point of the rod is? (IIT-JEE 1993)

8. In Searle's experiment, which is used to find Young's modulus of elasticity, the diameter of the experimental wire is $D = 0.05$ cm (measured by a scale of least count 0.001 cm) and length is $L = 110$ cm (measured by a scale of least count 0.1 cm). A weight of 50 N causes an extension of $l = 0.125$ cm (measured by a micrometer of least count 0.001 cm). Find maximum possible error in the values of Young's modulus. Screw gauge and meter scale are free from error (IIT-JEE 2004)

"Pressure and Volumetric Strain, Bulk Modulus of Elasticity"

Single Correct

9. A given quantity of an ideal gas is at pressure p and absolute temperature T. The isothermal bulk modulus of the gas is (IIT-JEE 1998)
(a) 2/3 p (b) p (c) 3/2 p (d) 2p

@FAKE CREEK @RAHEDUNET

10. The pressure of a medium is changed from $1.01 \times 10^5 Pa$ to $1.165 \times 10^5 Pa$ and change in volume is 10% keeping temperature constant. The bulk modulus of the medium is **(IIT-JEE 2005)**
(a) 204.8×10^5 Pa
(b) 102.4×10^5 Pa
(c) 51.2×10^5 Pa
(d) 1.55×10^5 Pa

11. When a block of iron floats in mercury at 0° C, fraction k_1 of its volume is submerged, while at the temperature 60° C, a fraction k_2 is seen to be submerged. If the coefficient of volume expansion of iron is γ_{Fe} and that of mercury is γ_{Hg}, then the ratio k_1/k_2 can be expressed as **(IIT-JEE 2001)**
(a) $(1 + 60\gamma_{Fe})/(1 + 60\gamma_{Hg})$
(b) $(1 - 60\gamma_{Fe})/(1 + 60\gamma_{Hg})$
(c) $(1 + 60\gamma_{Fe})/(1 - 60\gamma_{Hg})$
(d) $(1 + 60\gamma_{Hg})/(1 + 60\gamma_{Fe})$

Fill In the Blanks

12. A solid sphere of radius R made of a material of bulk modulus k is surrounded by a liquid in a cylindrical container. A massless piston of area A floats on the surface of the liquid. When a mass M is placed on the piston to compress the liquid the fractional change in the radius of the sphere, $\delta R/R$, is ..... **(IIT JEE 1993)**

13. A wire of length L and cross-sectional area A is made of a material of Young's modulus Y. If the wire is stretched by an amount x, the work done is _____. **(IIT-JEE 1987)**

Subjective

14. A thin rod of negligible mass and area of cross-section 4×10^{-6} m^2 is suspended vertically from one end, has a length of 0.5 m at 100°C. The rod is cooled to 0°C, but prevented from contracting by attaching a mass at the lower end. Find **(IIT-JEE 1997)**
(a) This mass
(b) The energy stored in the rod, given for the rod. [Young's modulus = 10^{11} N/m^2, coefficient of linear expansion = 10^{-5} K^{-1} and $g = 10$ m/s^2].

@FAKE_CBSE X @RAJ_EDUNET

ANSWER KEY

JEE-Main

1. (c)	2. (d)	3. [16]	4. (c)	5. [2]	6. [12]	7. [3]	8. [5]	9. [600]	10. [1]
11. [20]	12. (d)	13. (c)	14. [5]	15. (d)	16. (b)	17. (c)	18. [25]	19. [11]	20. [20]
21. (b)	22. [2]	23. (b)	24. [6]	25. (c)	26. [5]	27. [25]	28. (a)	29. [2]	30. (a)
31. [30]	32. (a)	33. (b)	34. [2]	35. (c)	36. [32]	37. (a)	38. (c)	39. (d)	40. [40]
41. (b)	42. (b)	43. (a)	44. (a)	45. (a)	46. (d)	47. (b)	48. (c)	49. (*)	50. (a)
51. (c)	52. [2]	53. (c)	54. (a)	55. [1]	56. (a)	57. [40]	58. (c)	59. [25]	60. [3]
61. (d)	62. (d)	63. [20]	64. [500]	65. (d)	66. (c)				

JEE-Advanced

1. (c)	2. (a)	3. (c)	4. (a)	5. (a, b)	6. [2]	9. (b)	10. (d)	11. (a)

EXPLANATIONS

JEE-Main

1. (c) Conceptual

2. (d) Let Y be the young's modulus of the material of the wire

$$Y=\frac{\text{stress}}{\text{strain}}$$

Length of wire = L

Radius of wire = r

Applied force = F

Increase in length = l

$$Y=\frac{\frac{F}{\pi r^2}}{\frac{l}{L}}$$

$$F=Ypr^2\times\frac{l}{L} \quad ...(i)$$

$$Y=\frac{\frac{F/2}{\pi r^2/4}}{\frac{\Delta l}{L}}$$

$$F=Y\frac{\Delta l}{L}\times 2\times\frac{\pi r^2}{4}$$

From (i)

$$Y\pi r^2\frac{l}{L}=Y\frac{\Delta l}{L}\frac{\pi r^2}{2}$$

$\Delta l = 2l$

the increase in length will become 2l.

3. [16] Let Y be the young's modulus of the material of the wire

$$Y=\frac{\text{Stress}}{\text{Strain}}=\frac{F/A}{\Delta l/l}=\frac{Fl}{A\Delta l}$$

$$\Delta l=\frac{Fl}{Ay}$$

$$V=Al\Rightarrow l\frac{V}{A}$$

$$\Delta l=\frac{FV}{A^2Y}$$

Y and V is same for both the wires

$$\Delta l\propto\frac{F}{A^2}$$

$$\frac{\Delta l_1}{\Delta l_2}=\frac{F_1}{A_1^2}\times\frac{A_2^2}{F_2}$$

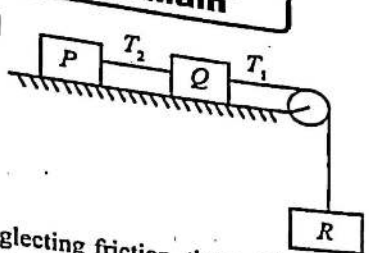
$\Delta l_1=\Delta l_2$

$F_1A_2^2=F_2A_1^2$

$$\frac{F_1}{F_2}=\frac{A_1^2}{A_2^2}=\left(\frac{4}{1}\right)^2=16$$

4. (c) Young's modulus is determined by the material and remains constant regardless of changes in length and cross-sectional area.

5. [2]



Neglecting friction, the net force acting on each block is its mass multiplied by the common acceleration a.

The equations of motion for the system can be written as follows:

For block P:

$T2 = (3\text{ kg}) \times a$

For block Q:

$T_1 - T_2 = (3\text{ kg}) \times a$

For block R:

$(3\text{ kg}) \times g - T1 = (3\text{ kg}) \times a$

After solving above equation we get,

$$a=\frac{10}{3}\text{ m/s}^2$$

$T1 = 20$ N

Now,

The longitudinal strain on wire B can be calculated using Hooke's Law:

$$\text{Strain}=\frac{\text{Longitudinal stress}}{\text{Young's modulus}}$$

$$\text{strain}=\frac{\text{stress}}{Y}=2\times 10{-}4$$

6. [12] Tension, $T=\left(\frac{2m_1m_2}{m_1+m_2}\right)g=\frac{80}{3}$N

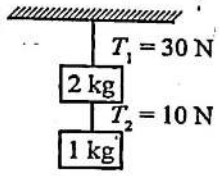
Area, $A=\pi r^2\doteq 16\pi\times 10{-}10\text{ m}^2$

$$\text{Strain}=\frac{\Delta\ell}{\ell}=\frac{F}{AY}=\frac{T}{AY}$$

$$=\frac{80/3}{16\pi\times10^{-10}\times2\times10^{11}}=\frac{1}{12\pi}$$

$\alpha = 12$

7. [3]



As, $\Delta L=\frac{FL}{AY}$

Longitudinal strain,

$$\frac{\Delta L}{L}=\frac{F}{AY}$$

$$\Rightarrow\frac{\frac{\Delta L_1}{L_1}}{\frac{\Delta L_2}{L_2}}=\frac{F_1}{F_2}=\frac{30}{10}=3$$

8. [5] For F = 3N

$3=K(a-\ell)$

For F = 2N

$2=K(b-\ell)$

Now, $T=K(3a-2b-\ell)$

$\Rightarrow T=K(3(a-\ell)-2(b-\ell)$

$$=K\left[3\left(\frac{3}{K}\right)-2\left(\frac{2}{K}\right)\right]=9-4=5\text{ N}$$

9. [600]

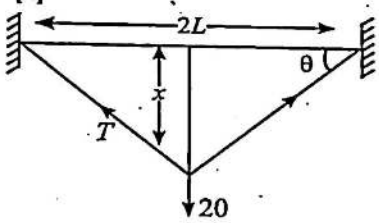
Here, net force in the vertical direction is zero. so,

$T = mg$

$$\sigma=\frac{T}{A}=\frac{mg}{A}=\frac{(\rho A\ell)g}{A}$$

$$\Rightarrow\ell=\frac{\sigma}{\rho g}=\frac{1.2\times10^8\times3}{6\times10^4\times10}=600$$

10. [1]



In vertical derection

$2T \sin q = 20\text{ u} \sin g$,

using $\sin q \approx q$

$$\theta=\frac{1}{100}$$

$$\therefore T=\frac{10}{\theta}=1000\text{ N}$$

$$\Delta L=2\sqrt{x^2+L^2}-2L=2L\left[1+\frac{x^2}{2L^2}-1\right]$$

$$\Delta L=\frac{x^2}{L}$$

∴ Modulus of elasticity (Y)

$$=\frac{\text{stress}(T)}{\text{strain}\left(\frac{\Delta L}{L}\right)}$$

$$2\times10^{11}=\frac{10^3}{A\times\frac{x^2}{L}}\times2L$$

$\therefore A = 1\times10^{-4}\text{ m}^2$

@FAKE_CBSE_TOPPERS_RAJ_EDUNET

11. [20] Stress $= \frac{F}{A} = Y\frac{\Delta\ell}{\ell} \Rightarrow \Delta\ell = \frac{F\ell}{AY}$

$\Delta\ell = \frac{200\times 2}{2\times10^{-4}\times10^{11}} = 2\times10^{-5} = 20\mu m$

12. (*d*) Elongation in the wire is given by

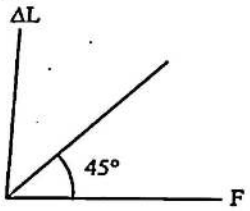
$\delta = \frac{F\ell}{AY}$

$\delta = \frac{250\times100}{6.25\times10^{-4}\times10^{10}}$

$\Rightarrow \delta = 4\times10^{-3}\,m$

13. (*c*) Concept based

14. [5]



Using the graph:

F = ΔL at every point of the graph

$\because Y = \frac{FL}{A\Delta L} \Rightarrow Y = \frac{L}{A}$ $(\because F = \Delta L)$

$\Rightarrow Y = \frac{62.8\times10^{-2}}{\pi\left(2\times10^{-3}\right)^2}$

$\therefore Y = 5\times10^4\ N/m^2$

15. (*d*) $Y = \frac{F/A}{\frac{\Delta\ell}{\ell}} \Rightarrow F = \frac{YA}{\ell}\Delta\ell$

$\left(\frac{A\Delta\ell}{\ell}\right)_1 = \left(\frac{A\Delta\ell}{\ell}\right)_2$

$\Rightarrow \frac{\Delta\ell_2}{\Delta\ell_1} = \frac{A_1}{A_2}\times\frac{\ell_2}{\ell_1}$

$\Rightarrow \frac{\Delta\ell_2}{0.2} = \frac{1}{2.4\times2.4}\times\frac{2}{1}$

$\Rightarrow \Delta\ell^2 = 6.9\times10^{-2}$ mm

16. (*b*) We know that,

stress ∝ strain

$\frac{F}{A} = Y\frac{\Delta L}{L}$

$\Rightarrow \frac{F_1}{A_1} = Y_1\times\frac{\Delta L}{L_1}$ ...(*i*)

And $\frac{F_2}{A_2} = Y_2\times\frac{\Delta L}{L_2}$ ...(*ii*)

from equation (*i*) and (*ii*),

$\frac{F_1L_1}{A_1Y_1} = \frac{F_2L_2}{A_2Y_2}$

$\frac{5}{2.5\times10^{-5}\times Y_1} = \frac{6}{3\times10^{-5}\times Y_2}$

$\frac{Y_1}{Y_2} = 1$

17. (*c*) Tension $(F) = mg$

$= 4\times\frac{10}{4} = 10\,N$

Elongation produced in the wire is,

$\Delta L = \frac{FL}{AY} = \frac{10\times6}{3\times10^{-6}\times2\times10^{11}} = 0.1mm$

18. [25] Strain $= \frac{\text{stress}}{Y} = \frac{\frac{62.8\times10^3}{3.14\times(0.02)^2}}{2\times10^{11}}$

$= 2.5\times10^{-4} = 25\times10^{-5}$

19. [11] Tensile stress, $\sigma = \frac{F}{A} = \frac{4mg}{\pi D^2}$

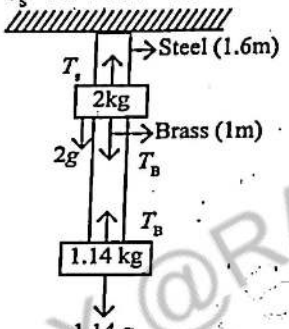
$\Rightarrow m = \frac{\pi D^2\sigma}{4g}$

$m = 3.14\times\frac{\left(14\times10^{-3}\right)^2\times7\times10^5}{4\times9.8} = 11$ kg

20. [20] Tension in steel wire

$T_S = 2g + T_B$

$T_S = 20 + 11.4 = 31.4\,N$



For steel wire $\Delta L = \frac{T_S L}{Ay}$

$\Delta L = \frac{31.4\times1.6}{\pi\left(0.2\times10^{-2}\right)^2\times2\times10^{11}}$

$= 20\times10^{-6}\,m$

21. (*b*) Elongation, $\Delta L = \frac{FL}{AY} \Rightarrow \Delta L \propto \frac{1}{Ay}$

$\therefore \frac{\Delta L_A}{\Delta L_B} = \left(\frac{A_B}{A_A}\right)\left(\frac{Y_B}{Y_A}\right) = \left(\frac{3}{1}\right)\left(\frac{4}{1}\right) = \frac{12}{1}$

22. [2] Given, $10\ell_2 = 11\ell_1 \Rightarrow \ell_2 = 1.1\,\ell_1$

Let the natural length be 'ℓ_0'.

When T_1 =100 N, Extension = $\ell_1 - \ell_0$

Then $10\ \ 0 = K(\ell_1 - \ell_0)$... (*i*)

When T_1 =120 N, Extension = $\ell_2 - \ell_0$

Then $120 = K(\ell_2 - \ell_0)$... (*ii*)

$\frac{120}{100} = \frac{\ell_2 - \ell_0}{\ell_1 - \ell_0}$

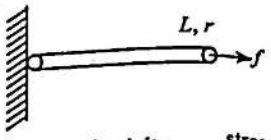
$1.2 = \frac{1.1\ell_1 - \ell_0}{\ell_1 - \ell_0}$

$0.1\,\ell_1 = 0.2\,\ell_0$

$\ell_0 = \frac{\ell_1}{2}$

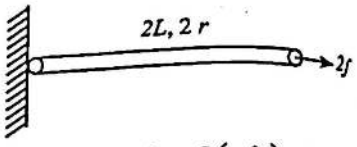
$\therefore x = 2$

23. (*b*)



Formula of elasticity, $Y = \frac{\text{stress}}{\text{strain}} = \frac{f}{\pi r^2}\cdot\frac{L}{\ell}$

$\frac{f}{\pi r^2} = Y\frac{\ell}{L}$ ...(*i*)



$\frac{2f}{\pi(2r)^2} = Y\frac{\ell'}{2L} \Rightarrow \frac{2}{4}\left(\frac{f}{\pi r^2}\right) = \frac{Yl'}{2L}$

$\frac{1}{2}\cdot\frac{Yl}{L} = \frac{Yl'}{2L} \Rightarrow \ell' = \ell$

24. [6] $\Delta L = \frac{F\ell}{AE} = \frac{mg\ell}{AE}$

$\therefore \frac{\Delta\ell_1}{g_1} = \frac{\Delta\ell_2}{g_2} \Rightarrow \frac{10^{-4}}{10} = \frac{6\times10^{-5}}{g_1}$

$g_1 = \frac{6\times10^{-4}}{10^{-4}} = 6\ m/sec^2$

25. (*c*) By using Hooke's Law

$F \propto \Delta L$.

$\frac{F_1}{F_2} = \frac{\Delta L_1}{\Delta L_2} \Rightarrow \frac{10}{20} = \frac{L_1 - L}{L_2 - L} \Rightarrow L = 2L_1 - L_2$

26. [5] $\frac{F}{A} = Y\times\frac{\Delta L_1}{L}$

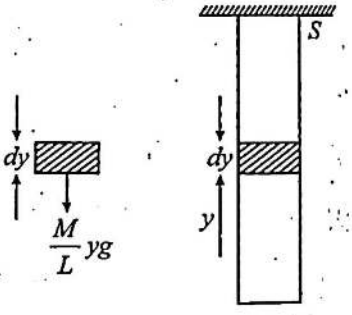
$\Rightarrow \frac{F}{\pi r^2} = Y\times\frac{5}{L}$ ...(i)

$\frac{4F}{\pi\cdot r^2\times16} = Y\times\frac{\Delta L_2}{4L}$ ...(ii)

$\Delta L_2 = 5$

27. [25] Let *dl* be small elongation due to

$\frac{MY}{L}g$



@RAKE_CBSE_K @RAJ_EDUNET

Using $\frac{F}{A}=Y\frac{\Delta l}{l}\Rightarrow\frac{MYg}{AL}=Y.\frac{dl}{dy}$

$\therefore\int dl=\frac{Mg}{YAL}\int_0^L ydy\Rightarrow\Delta l=\frac{MgL}{2AY}$

$\Delta l=\frac{MgL}{2AY}$; $\Delta l=\frac{20\times10\times20}{2\times0.4\times2\times10^{11}}$

$=25\times10^{-9}$ m

28. (*a*) Stress = $\frac{\text{Weight}}{\text{Area}}$

$\Rightarrow\frac{10}{2.5\times10^{-4}}=\frac{25}{A}\Rightarrow A=6.25\times10^{-4}$

29. [2] Slope of the curve

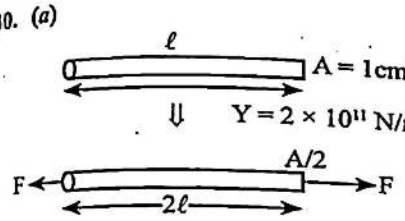
$=\frac{\Delta L/W}{L}=\frac{\Delta L/L}{W}=\frac{1}{YA}$

$Y=\frac{1}{(\text{Slope})\times A}$

$Y=\frac{1}{(0.25\times10^{-5})\times(2\times10^{-6})}$

$Y=2\times10^{11}\ N/m^2$

30. (*a*)



At steady state:

$F=\frac{YA}{2}=\frac{2\times10^{11}\times10^{-4}}{2}=10^7$N

31. [30] For circular motion:

$T-mg=\frac{mv^2}{r}\Rightarrow T=m\left(g+\frac{v^2}{r}\right)$

$=2\left(10+\frac{25}{1/2}\right)=120N$

$\Rightarrow$ Strain = $\frac{\text{stress}}{\text{Young's Modules}}$

$=\frac{T}{AY}=\frac{120}{4\times10^{-6}\times10^{11}}=30\times10^{-5}$

32. (*a*) Young's modulus is independent of dimensional parameter of a body.

33. (*b*) *If* μ is Poisson's ratio,

$Y=3K(1-2\mu)$ ...(*i*)

$Y=3\eta(1+\mu)$ ...(*ii*)

On soliving (*i*) and (*ii*), we get

$\frac{3}{Y}=\frac{1}{\eta}+\frac{1}{3k}\Rightarrow K=\frac{\eta Y}{9\eta-3Y}$

34. [2] As we know that, $Y=\frac{FL}{A\Delta L}$

$\Delta L=0.04m=\frac{FL}{AY}$

If length and diameter both are double

$\Delta L'=\frac{F.2L}{4A.Y}=\frac{FL}{2Y}=0.02$ m = 2 cm

35. (*c*) Stress = Y × strain

$\Rightarrow\frac{T_1}{A}=Y_1\times\frac{(\ell_1-\ell)}{\ell}\Rightarrow Y_1=\frac{T_1\ell}{A(\ell_1-\ell)}$

$\frac{T_2}{A}=Y_2\times\frac{(\ell_2-\ell)}{\ell}\Rightarrow Y_2=\frac{T_2\ell}{A(\ell_2-\ell)}$

$\because y_1=y_2$

$\frac{T_1\ell}{A(\ell_1-\ell)}=\frac{T_2\ell}{A(\ell_2-\ell)}$

$\frac{T_1}{T_2}=\frac{\ell_1-\ell}{\ell_2-\ell}$

$T_1\ell_2-T_1\ell=T_2\ell_1-T_2\ell$

$\ell=\frac{T_2\ell_1-T_1\ell_2}{T_2-T_1}$

36. [32] $\rho_A=\rho_B$

$r_B=4r_A$

$\Delta l_a=2$ mm

$\Delta l_B=4$ mm

$Y=\frac{\text{stress}}{\text{strain}}=\frac{F/A}{\Delta\ell/\ell}\Rightarrow\ell=\frac{AY\Delta\ell}{F}$

$\Rightarrow\frac{\ell_a}{\ell_b}=\frac{\pi r_a^2\times Y\times\Delta\ell_a\times F}{\pi r_b^2\times Y\times\Delta\ell_b\times F}$

$\Rightarrow\frac{\ell_a}{\ell_b}=\frac{r_a^2\times\Delta\ell_a}{r_b^2\times\Delta\ell_b}=\frac{r_b^2\times2}{(4r_a)^2\times4}=\frac{r_d^2}{16r^2\times2}$

$\Rightarrow\frac{\ell_a}{\ell_b}=\frac{1}{32}\Rightarrow x=32$

37. (*a*) Since, $T_1\propto(\ell_1-\ell)$, and $T_2\propto(\ell_2-\ell)$

$\frac{T_1}{T_2}=\frac{\ell_1-\ell}{\ell_2-\ell}\Rightarrow\ell=\frac{T_1\ell_2-T_2\ell_1}{T_1-T_2}$

38. (*c*) Given that,

Length of the metal wire is ℓ_1 when the tension is T_1

Length of the metal wire is ℓ_2 when the tension is T_2

Using Hooke's law,

$T_1\propto(\ell_1-\ell)$, and $T_2\propto(\ell_2-\ell)$

$\therefore\frac{T_1}{T_2}=\frac{\ell_1-\ell}{\ell_2-\ell}\Rightarrow\ell=\frac{T_2\ell_1-T_1\ell_2}{T_2-T_1}$

39. (*d*) Young's modulus of wire 1

$Y_1=\frac{F/A}{\Delta\ell_1/\ell}\Rightarrow\frac{\Delta\ell_1}{\ell}=\frac{F/A}{Y_1}$

Young's modulus of wire 2

$Y_2=\frac{F/A}{\Delta\ell_2/\ell}\Rightarrow\frac{\Delta\ell_2}{\ell}=\frac{F/A}{Y_1}$

Young's modulus of the combination.

$Y=\frac{F/A}{\left(\frac{\Delta\ell_1+\Delta\ell_2}{2\ell}\right)}=\frac{F/A}{\frac{1}{2}\left[\frac{\Delta\ell_1}{\ell}+\frac{\Delta\ell_2}{\ell}\right]}$

$\frac{F/A}{\frac{1}{2}\times\left[\frac{F}{AY_1}+\frac{F}{AY_2}\right]}=\frac{2Y_1Y_2}{Y_1+Y_2}$

40. [40] Given,

Cross-sectional area of $W_1=8\times10^{-7}$ m²

Cross-sectional area of $W_2=4\times10^{-7}$ m²

For W_1,

Breaking stress = 1.25×10^9 N/m²

$\frac{(m+10+20)\times10}{8\times10^{-7}}\le1.25\times10^9$

$\Rightarrow m\le70$kg

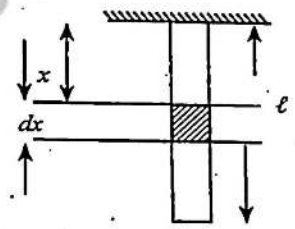
For W_2:

Breaking stress = 1.25 × 109 N/m²

$\frac{(m+10)\times10}{4\times10^{-7}}\le1.25\times10^9\Rightarrow m\le40$kg

Thus, $m\le40$kg

41. (*b*)



We have given a uniform heavy rod of weight, $W=10$ kg m/s², Cross-sectional area of rod, A = 100 cm², length of rod, ℓ = 20 cm, Young's modulus of the material of the rod, $Y=2\times10^{11}$ N/m²

$Y=\frac{F\ell}{A\Delta\ell}\Rightarrow\Delta\ell=\frac{F\ell}{AY}$

For elemental mass of length, dx change in its length

$d(\Delta\ell)=\frac{\frac{W}{\ell}(\ell-x)\cdot dx}{AY}$

$\therefore\Delta\ell=\int d(\Delta\ell)=\int_0^{\ell}\frac{W}{A\ell y}(\ell-x)dx$

$\Delta\ell=\frac{1}{2}\frac{W\ell}{AY}$

On putting values we get

$\Delta\ell=5\times10^{-10}$ m

42. (*b*) So force on each columns will be

$=\frac{mg}{4}=125\times10^3$ N.

Thus Strain

$\varepsilon=\frac{F}{AY}=\frac{125\times10^3}{2.355\times2\times10^{11}}=2.65\times10^{-7}$

@FAKE_CBSE_RAJ_EDUNET

43. (a) Given, $M = 6g = 6 \times 10^{-3}$ kg
$L = 60$ cm
$A = 1$ mm^2

As, $v = \sqrt{\frac{T}{m}} \Rightarrow T = \mu v^2$;

$\Rightarrow \frac{\mu v^2}{A} = Y\frac{\Delta \ell}{\ell} \Rightarrow T = v^2 \times \frac{M}{\ell}$ ...(i)

As, strain $= \frac{T}{Ay} \Rightarrow \frac{\Delta \ell}{\ell} = \frac{T}{AY}$

from eqn (i)

$\Rightarrow \Delta \ell = \frac{V^2 M}{Ay}$

$\therefore \Delta \ell = \frac{8100 \times 6 \times 10^{-3}}{1 \times 10^{-6} \times 16 \times 10^{11}} = 0.03$ mm

44. (a) $\Delta L = L\alpha\Delta T$

Strain $= \frac{\Delta L}{L} = \alpha \Delta T$; Y

$= \frac{\text{stress}}{\text{strain}} = \frac{\frac{F}{A}}{\frac{\Delta L}{L}} = \frac{F}{A\alpha\Delta T}$

45. (a) In first case:

$\frac{\frac{mg}{A}}{\left(\frac{\Delta \ell_1}{\ell}\right)} = Y \Rightarrow \Delta \ell_1 = \frac{mg}{\left(\frac{YA}{\ell}\right)}$

In second case:

$\frac{\frac{mg - B}{A}}{\left(\frac{\Delta \ell_1}{\ell}\right)} = Y \Rightarrow \Delta \ell_2 = \frac{mg - B}{\left(\frac{YA}{\ell}\right)} = \frac{\left(\frac{3mg}{4}\right)}{\left(\frac{YA}{\ell}\right)}$

$\Rightarrow \Delta \ell_2 = \frac{3}{4}\Delta \ell_1 = 3$ mm

46. (d) Tensile stress in wire will be

$= \frac{\text{Tensile force}}{\text{Cross-section area}} = \frac{mg}{\pi R^2} = \frac{4 \times 3.1\pi}{\pi \times 4 \times 10^{-6}}$

$\text{Nm}^{-2} = 3.1 \times 10^6 \text{ Nm}^{-2}$

47. (b) Given, $\frac{Y_A}{Y_B} = \frac{7}{4}$

$L_A = 2$ m $A_A = \pi R^2$

$L_B = 1.5$ m $A_B = \pi$ (2 mm)^2

$\frac{F}{A} = Y\left(\frac{\ell}{L}\right)$

Since F and ℓ are same $\Rightarrow \frac{AY}{L}$ is same

$\frac{A_A Y_A}{L_A} = \frac{A_B Y_B}{L_B}$

$\Rightarrow \frac{\left(\pi R^2\right)\left(\frac{7}{4}Y_B\right)}{2} = \frac{\pi (2 \text{ mm})^2 . Y_B}{1.5}$

$R = 1.74$ mm

48. (c) Energy of catapult

$= \frac{1}{2} \times \left(\frac{\Delta \ell}{\ell}\right)^2 \times Y \times A \times \ell$

= Kinetic energy of the ball $= \frac{1}{2}mv^2$

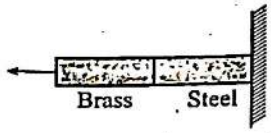
therefore,

$\frac{1}{2} \times \left(\frac{20}{42}\right)^2 \times Y \times \pi \times 3^2 \times 10^{-6} \times 42 \times 10^{-2}$

$= \frac{1}{2} \times 2 \times 10^{-2} \times (20)^2$

$Y = 3 \times 106 \text{ Nm}^{-2}$

49. (*)



$k_1 = \frac{y_1 A_1}{\ell_1} = \frac{120 \times 10^9 \times A}{1}$

$k_2 = \frac{y_2 A_2}{\ell_2} = \frac{60 \times 10^9 \times A}{1}$

$k_{eq} = \frac{k_1 k_2}{k_1 + k_2} = \frac{120 \times 60}{180} \times 10^9 \times A$

$k_{eq} = 40 \times 10^9 \times A$

$F = k_{eq}(x)$

$F = (40 \times 10^9) A . (0.2 \times 10^{-3})$

$\frac{F}{A} = 8 \times 10^6 \text{ N/m}^2$

No option is matching. Here question must be bonus.

50. (a) $\frac{F}{A} = \text{stress}$; $\frac{400 \times 4}{\pi d^2} = 379 \times 10^6$

$d^2 = \frac{1600}{\pi \times 379 \times 10^6} = 1.34 \times 10^{-6}$

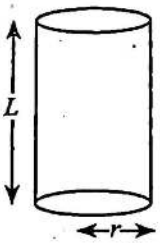
$d = \sqrt{1.34} \times 10^{-3} = 1.15 \times 10^{-3}$ m

51. (c) As length is same

So $\left(\frac{F}{A}\right)_{\text{Compressive}} = \left(\frac{F}{A}\right)_{\text{Thermal}}$

$\frac{F}{\pi r^2} = Y\alpha T$

linear coefficient of expansion $\alpha = \frac{F}{YT\pi r^2}$

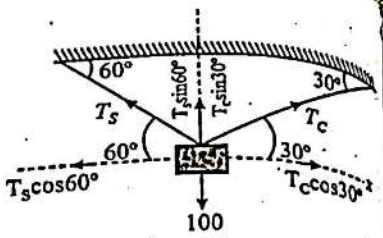


$\therefore$ The coefficient of volume expansion $\gamma = 3\alpha$

$\therefore \gamma = 3\frac{F}{YT\pi r^2}$

52. [2] Let T_s = tension in steel wire

T_c = Tension in copper wire in x direction



$T_c \cos 30° = T_s \cos 60°$

$T_c \times \frac{\sqrt{3}}{2} = T_s \times \frac{1}{2}$

$\sqrt{3}\ T_c = T_s$

in y direction

$T_c \sin 30° + T_s \sin 60° = 100$

$\frac{T_C}{2} + \frac{T_S\sqrt{3}}{2} = 100$

Solving equation (i) and (ii)

$T_c = 50$N

$T_s = 50\sqrt{3}N$

We know

$\Delta L = \frac{FL}{AY} = \frac{\Delta L_C}{\Delta L_S} = \frac{T_C L_C}{A_C Y_C} \times \frac{A_S Y_S}{T_S L_S}$

On solving above equation

$\frac{\Delta L_C}{\Delta L_S} = 2$

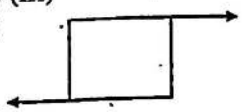
53. (c) (A) stress $= \frac{F_{restoring}}{A}$

If A = 1

Stress $= F_{\text{restoring}}$

(A)-(III)

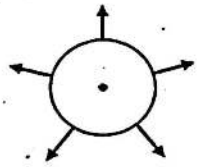
(B)



$\Rightarrow$ **Shear stress**

(B)-(IV)

(C)



$\Rightarrow$ **Volumetric stress**

(C)-(I)

(D)

$\Rightarrow$ **Longitudinal stress**

(D)-(II)

54. (a) $Y = 3\eta(1+\sigma)$

$Y = 3K(1-\sigma)$

$\Rightarrow 2\eta(1+\sigma) = 3K(1-2\sigma)$

$\Rightarrow \sigma = \left(\frac{3K - 2\eta}{6K + 2\eta}\right)$

@RAKE_CBSE_X_@RAJ_EDUNET

55. [1] Bulk modules for water,

$$B_{water}=\frac{-\Delta P}{\left(\frac{\Delta V}{V}\right)}=\frac{-\Delta P}{\frac{0.01}{100}}$$

Bulk modules for the liquid, $B_{liquid}=\frac{-\Delta P}{\frac{0.03}{100}}$

$$\Rightarrow \frac{B_{water}}{B_{liquid}}=3$$

$$\therefore x=1$$

56. (a) Strain $=\frac{0.04}{100}$

Energy per unit volume is

$$\frac{E}{V}=\frac{1}{2}\times Y\times \text{strain}^2$$

$$=\frac{1}{2}\times 7\times 10^{10}\times\frac{(0.04)^2}{(100)^2}=56\times 10^2$$

57. [40] Energy $=\frac{1}{2}$ stress × strain × volume

$$U=\frac{1}{2}\times Y\times \text{strain}^2 A\times \ell$$

$$\Rightarrow A=\frac{2U}{Y\times(\text{strain})^2\times\ell}$$

$$=\frac{2\times 80}{2\times 10^{11}\times\left(\frac{2\times10^{-2}}{20}\right)^2\times 20}$$

$$=40\times 10^{-6}\ m^2=40\ mm^2$$

$$80=\frac{1}{2}\times 2\times 10^{11}\times\frac{(2\times10^{-2})^2}{400}\times A\times 20$$

$$20=\frac{10^{+7}}{20}\times A=40\times 10^{-6}\ m^2=A$$

$$A=40\ mm^2$$

58. (c) Bulk modules, $B=-\frac{\Delta P}{\frac{\Delta V}{V}}$

$$\therefore \Delta P=-B\frac{\Delta V}{V}$$

Given, $\frac{DV}{V}=0.02$

$$\Delta P=-3\times 10^{10}(0.02)$$

$$\Delta P=6\times 10^{8}\ Nm^{-2}$$

59. [25] $y=\frac{\text{stress}}{\text{strain}}=2.0\times10^{10}$

Energy density $=\frac{1}{2}$ stress × strain

$$=\frac{1}{2}(\text{strain})^2 y=\frac{1}{2}(5\times10^{-4})^2\times20\times10^{10}$$

$$=25\times10^2\times10=25\frac{kJ}{m^3}$$

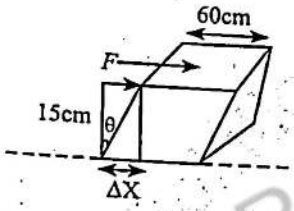
60. [3] Share modulus $=25\times10^8\ N/m^2$

Formula of shear modulars

$$\eta=\frac{F/A}{x/\ell}\Rightarrow x=\frac{F\ell}{\eta A}$$

$$=\frac{18\times10^4\times60\times10^{-2}}{25\times10^9\times60\times15\times10^{-4}}$$

$$=48\times10^{-6}\ m=48\ \mu m.$$



61. (d) We know that $K=-V\frac{dp}{dv}$

Also as mass remains constant we have

$$\frac{dv}{v}=\frac{d\rho}{\rho}$$

This we get, $K=-\rho\frac{dp}{d\rho}$

Hence, $dp=p$

So, $d\rho=-\frac{\rho p}{K}$

62. (d) Bulk modules $B=\frac{\rho gh}{\frac{\Delta V}{V}}$

$$=\frac{10^3\times9.8\times2\times10^3}{1.36\times10^{-2}}$$

$$=1.44\times10^9\ N/m^2$$

63. [20] We know that, energy conservation

According to energy conservation

$$\frac{1}{2}\cdot\frac{YA}{L}\cdot x^2=\frac{1}{2}mv^2$$

Putting all values in above equation we get,

$$\frac{0.5\times10^9\times10^{-6}\times(0.04)^2}{0.1}=\frac{20}{1000}v^2$$

$$\therefore v^2=400\Rightarrow v=20\ m/s$$

The velocity of the projected stone is 20 m/s.

64. [500] $B=\frac{-P}{\left(\frac{\Delta V}{V}\right)}$

$$B=\frac{-(\rho gh)}{\left(\frac{-0.5\%\ of\ V_0}{V_0}\right)}\Rightarrow h=500\ m$$

$$=\frac{9.8\times10^8\times0.005}{10^3\times9.8}$$

Hence, depth = 500 m

65. (d) $\frac{du}{dv}=\frac{1}{2}\text{stress}\times\frac{\text{stress}}{y}=\frac{1}{2}\frac{F^2}{A^2y}$

$$\frac{du}{dv}\propto\frac{1}{d^4}$$

$$\frac{\left(\frac{du}{dv}\right)_1}{\left(\frac{du}{dv}\right)_2}=\frac{d_2^4}{d_1^4}=\frac{1}{4}$$

$$\frac{d_1}{d_2}=(4)^{1/4}\ ;\ \frac{d_1}{d_2}=\sqrt{2}:1$$

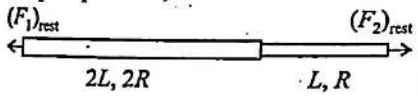
66. (c) $\frac{\Delta v}{v}=\frac{\Delta p}{B}=\frac{1}{20}$

$$\frac{\Delta\ell}{\ell}=\frac{1}{3}\frac{\Delta p}{B}=\frac{1}{60}$$

$$\frac{\Delta\ell}{\ell}\times100=\frac{1}{60}\times100=1.67\%$$

JEE-Advanced

1. (c) As per question,



We have change in length as

$$\Delta l=\frac{F\cdot l}{YA}$$

Since the two rods are in series ,we get

$(F_1)_{rest}=(F_2)_{rest}$

$$\Delta l\propto\frac{l}{R^2}\qquad(\because A=\pi R^2)$$

$$\therefore \frac{\Delta l_1}{\Delta l_2}=\frac{l_1}{l_2}\times\frac{R_2^2}{R_1^2}$$

$$\frac{\Delta l_1}{\Delta l_2}=\frac{2L}{L}\times\frac{R_1^2}{4R_1^2}$$

$$\frac{\Delta l_1}{\Delta l_2}=\frac{1}{2}$$

$$\therefore \frac{\Delta l_2}{\Delta l_1}=\frac{2}{1}=2$$

2. (a) By Young's Modulus,

$$Y=\frac{FL}{Al}=\frac{W\times1}{10^{-6}\times\Delta l}$$

$$Y=\frac{1}{10^{-6}\times\frac{\Delta l}{W}}$$

From the graph we can see the slope of

$$\frac{\Delta l}{W}=\frac{10^{-4}}{20}$$

@FAKE_CBSE_X_@RAJ_EDUNET

$$Y=\frac{1}{10^{-6}\times\frac{10^{-4}}{20}}$$

$$=20\times10^{10}=2\times10^{11}\ \text{N/m}^2$$

3. (*c*) By Using Young's Modulus,

$$Y=\frac{FL}{A\Delta l}$$

$$\frac{\Delta l}{L}=\alpha\Delta T$$

$$F=\frac{YA\Delta l}{L}=YA\alpha\Delta T$$

$$Y_1A\alpha_1\Delta T=Y_2A\alpha_2\Delta T$$

$$\frac{\alpha_1}{\alpha_2}=\frac{Y_2}{Y_1}$$

$$\frac{2}{3}=\frac{Y_1}{Y_2}$$

$$\frac{Y_1}{Y_2}=\frac{3}{2}$$

4. (*a*) Using Hooke's law $Y=\frac{FL}{A\Delta L}$ where

$$A=\frac{\pi D^2}{4}$$

$$\Rightarrow \Delta L=K\frac{L}{D^2}\ \text{where } K=\text{constant}$$

For wire A: $\frac{L}{D^2}=\frac{50}{(0.05)^2}=20000$

For wire B: $\frac{L}{D^2}=\frac{100}{(0.1)^2}=10000$

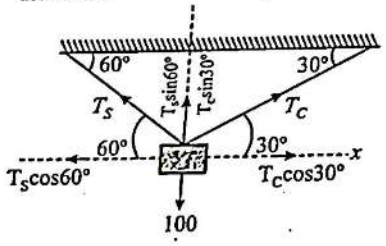
For wire C: $\frac{L}{D^2}=\frac{200}{(0.2)^2}=5000$

For wire D: $\frac{L}{D^2}=\frac{300}{(0.3)^2}=3333.33$

Thus wire A has the largest extension.

5. (*a,b*) As P can have more stress than Q before failing after proportional limit, thus P is more ductile than Q. Hence B is correct and C is incorrect.
The breaking stress of P is more than of Q, hence P has more tensile strength than Q.
For same stress, strain in P is higher than Q, hence, stress/strain ratio i.e., young's modulus, will be lower for P thus option d is incorrect.

6. [2] Let T_s = tension in steel wire
T_c = Tension in copper wire in x direction



$$T_c\cos30°=T_s\cos60°$$

$$T_c\times\frac{\sqrt{3}}{2}=T_s\times\frac{1}{2}$$

$$\sqrt{3}\,T_c=T_s \quad \ldots(i)$$

in y direction

$$T_c\sin30°+T_s\sin60°=100$$

$$\frac{T_C}{2}+\frac{T_S\sqrt{3}}{2}=100 \quad \ldots(ii)$$

Solving equation (*i*) and (*ii*)

$T_c=50\text{N}$

$T_s=50\sqrt{3}N$

We know

$$\Delta L=\frac{FL}{AY}$$

$$=\frac{\Delta L_C}{\Delta L_S}=\frac{T_CL_C}{A_CY_C}\times\frac{A_SY_S}{T_SL_S}$$

On solving above equation

$$\frac{\Delta L_C}{\Delta L_S}=2$$

7. m_{1n} = mass of first half of rod $\rho.V=\rho.(A.l)$ where, A is area and L is length

$$\rho\cdot A\frac{L}{2}=\frac{\rho AL}{2}$$

F acting on the cross section through the mid point of rod $=m_{1n}\times a=\frac{\rho AL}{2}\times a$

$$\text{Stress}(S)=\frac{F}{A}=\frac{\rho ALa}{2A}=\frac{\rho La}{2}$$

Therefore, $S=\frac{\rho La}{2}$

8. As, $\frac{mg}{\pi d^2/4}=Y\left(\frac{X}{l}\right)$

$$Y=\frac{Mgl}{(x/4)d^2x}$$

$m=20.0\text{ kg}\Rightarrow\Delta m=0.1\text{ kg}$

$l=0.125\text{ cm}\Rightarrow\Delta l=0.001\text{ cm}$

$d=0.050\text{ cm}\Rightarrow\Delta d=0.001\text{ cm}$

$L=110\text{ cm}\Rightarrow\Delta L=0.1\text{ cm}$

$$\left(\frac{dY}{Y}\right)_{\max}=\left(\frac{0.1\text{kg}}{20.0\text{kg}}+\frac{0.001\text{cm}}{0.125\text{cm}}+\frac{2\times0.001\text{cm}}{0.050\text{cm}}+\frac{0.1\text{cm}}{110\text{cm}}\right)\times100\%$$

$=0.0489$

$\Delta y=(0.0489)\times y$

$y=2.24\times10^{11}\text{ N/m}^2$

$\Delta y=1.09\times10^{10}$

9. (*b*) Isothermal bulk modulus is defined as the ratio of volumetric stress to volumetric strain at constant temperature.

Bulk modulus $\beta=-\frac{\Delta P}{\Delta v/v}$

for Isothermal Process $PV=\text{constant}$ ...(*i*)

Differentiating

$P(\Delta v)+(\Delta P)v=0$

$$\therefore\ \frac{\Delta P}{\Delta v/v}=P=\beta$$

Therefore $\beta=P$.

10. (*d*) As per question,

$\Delta p=1.165\times10^5-1.01\times105$

$=0.155\times10^5\text{ Pa}$

$$\frac{\Delta V}{V}=10\%=0.1$$

Now $K=\frac{\Delta D}{\frac{\Delta V}{V}}=\frac{0.155\times10^5}{0.1}$

$=1.55\times10^5\text{ Pa}$

11. (*a*) Let V_0 and V be the volume of the iron block at $T=0°C$ and 60°C, respectively then we can write

$V=V_0(1+60\gamma_{Fe})$ ...(*i*)

Let V_0' and V' be the volume of the iron block submerged in the mercury at $T=0°C$ and 60°C, respectively, then we can write

$V'=V_0'(1+60\gamma_{Fe})$ ...(*ii*)

Dividing (*i*) by (*ii*), we get

$$\frac{V}{V'}=\frac{V_0(1+60\gamma_{Fe})}{V_0'(1+60\gamma_{Hg})}$$

$$\Rightarrow\frac{1}{k_2}=\frac{1}{k_1}\frac{(1+60\gamma_{Fe})}{(1+60\gamma_{Hg})}$$

$$\because\frac{V_0'}{V_0}=k_1\text{ and}\frac{V'}{V}=k_2$$

$$\Rightarrow\frac{k_1}{k_2}=\frac{(1+60\gamma_{Fe})}{(1+60\gamma_{Hg})}$$

12. As, $k=\frac{-\Delta p}{\Delta V/V}$; where

$$\Delta p=\frac{Mg}{A}$$

$$\therefore-\frac{\Delta V}{V}=\frac{Mg}{Ak}$$

$$\Rightarrow-\frac{(V_f-V_i)}{V_i}=\frac{Mg}{Ak}$$

$$\Rightarrow-\frac{(V_i-V_f)}{V_i}=\frac{Mg}{Ak}$$

$$\Rightarrow\frac{\frac{4}{3}\pi R^3-\frac{4}{3}\pi(R-\delta R)^3}{\frac{4}{3}\pi R^3}=\frac{Mg}{Ak}$$

© TIME CBSE X CORRELATED DIGEST

$$\Rightarrow \frac{R^3-\left[R^2-3R^2\delta R\right]}{R^3}=\frac{Mg}{Ak}$$

$$\Rightarrow \frac{\delta R}{R}=\frac{Mg}{3Ak}$$

$$\therefore \frac{\Delta V}{V}=\frac{Mg}{Ak}$$

$$\Rightarrow -\frac{\left(V_f-V_i\right)}{V_i}=\frac{Mg}{Ak}$$

$$\Rightarrow -\frac{\left(V_i-V_f\right)}{V_i}=\frac{Mg}{Ak}$$

$$\Rightarrow \frac{\frac{4}{3}\pi R^3-\frac{4}{3}\pi(R-\delta R)^3}{\frac{4}{3}\pi R^3}=\frac{Mg}{Ak}$$

$$\Rightarrow \frac{R^3-\left[R^3-3R^2\delta R\right]}{R^3}=\frac{Mg}{Ak}$$

$$\Rightarrow \frac{\delta R}{R}=\frac{Mg}{3Ak}$$

13. Work done is equal to the potential energy stored in the wire.

$\therefore$ $W = U = 1/2 \times$ Stress $\times$ Strain $\times$ Volume

or $W = 1/2 \times Y$ (Strain)$^2 \times$ Volume ...(*i*)

(Strain $= Y \times$ Strain)

Strain $= X / L$ and Volume $= AL$

$$\therefore W=\frac{1}{2}\times Y\times\frac{x^2}{L^2}\times AL \Rightarrow W=\frac{Yx^2A}{2L}$$

14. The decrease in length of the Rod on cooling is

$\Delta L = L\alpha\Delta T = 0.5 \times 10^{-5} \times 100 = 5 \times 10^{-4}$ m

(*a*) If rod in presented from contacting, the mass m is attached at lover and must increase in length by an amount $\Delta L = 5 \times 10^{-4}$ m.

$$r=\frac{mgL}{A\Delta L}$$

$$m=\frac{rA\Delta L}{gL}=\frac{10^{11}\times4\times10^{-6}\times5\times10^{-4}}{10\times0.5}$$

$m = 40$ kg

(*b*) Energy stored in Rod is

$$u=\frac{1}{2}F\times\Delta L$$

$$u=\frac{1}{2}mg\Delta L$$

$$=\frac{1}{2}\times40\times10\times5\times10^{-4}=0.1\text{ J}$$

@FAKE_CBSE X @RAJ_EDUNET

11

Fluid Mechanics

Scan for Sol

JEE-Main

Pressure Variation Inside Fluid

1. If average depth of an ocean is 4000 m and the bulk modulus of water is 2×10^9 Nm^{-2}, then fractional compression $\frac{\Delta V}{V}$ of water at the bottom of ocean is $\alpha \times 10^{-2}$. The value of α is _____
(Given, g = 10 ms^{-2}, $\rho = 1000$ kg m^{-3}) [27 Jan, 2024 (Shift-I)]

2. The depth below the surface of sea to which a rubber ball be taken so as to decrease its volume by 0.02% is _____ m.
[31 Jan, 2024 (Shift-I)]
(Take density of sea water = 10^3 kgm^{-3}, Bulk modulus of rubber $= 9 \times 10^8$ Nm^{-2}, and $g = 10$ ms^{-2}) [31 Jan, 2024 (Shift-I)]

3. Mercury is filled in a tube of radius 2 cm up to a height of 30 cm. The force exerted by mercury on the bottom of the tube is ___N.
(Given, atmospheric pressure = 10^5 Nm^{-2}, density of mercury $= 1.36 \times 10^4$ kg m^{-3}, $g = 10$ ms^{-2}, $\pi = \frac{22}{7}$) [4 April, 2024 (Shift-II)]

4. An air bubble of volume 1cm^3 rises from the bottom of a lake 40 m deep to the surface at a temperature of 12° C. The atmospheric pressure is 1×10^5 Pa, the density of water is 1000 kg/m^3 and g = 10 m/s^2. There is no difference of the temperature of water at the depth of 40 m and on the surface. The volume of air bubble when it reaches the surface will be [08 April, 2023 (Shift-I)]
(a) 5 cm^3 (b) 2 cm^3 (c) 4 cm^3 (d) 3 cm^3

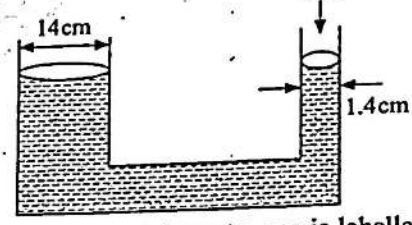
5. A hydraulic automobile lift is designed to lift vehicles of mass 5000 *kg*. The area of cross section of the cylinder carrying the load is 250 cm^2. The maximum pressure the smaller piston would have to bear is:
[Assume $g = 100$ m/s^2]: [08 April, 2023 (Shift-II)]
(a) $200 \times 10^{+6}$ Pa (b) $20 \times 10^{+6}$ Pa
(c) $2 \times 10^{+6}$ Pa (d) $2 \times 10^{+5}$ Pa

5. Two cylindrical vessels of equal cross-sectional area 16 cm^2 contain water upto heights 100 cm and 150 cm respectively. The vessels are interconnected so that the water levels in them become equal. The work done by the force of gravity during the process, is [Take density of water = 10^3 kg/m^3 and g = 10 m/s^2]
[27 July, 2022 (Shift-I)]
(a) 0.25 J (b) 1 J (c) 8 J (d) 12 J

7. The pressure acting on a submarine is 3×10^5 Pa at a certain dep If the depth is doubled, the percentage in the pressure acting on submarine would be:
(Assume that atmospheric pressure is 1×10^5 Pa density of wa is 10^3 kgm^{-3}, $g = 10$ ms^{-2}) [16 March, 2021 (Shift-
(a) $\frac{3}{200}\%$ (b) $\frac{5}{200}\%$
(c) $\frac{200}{3}\%$ (d) $\frac{200}{5}\%$

Pascal's Law

8. A hydraulic press containing water has two arms with diameters mentioned in the figure. A force of 10 N is applied on the surfa of water in the thinner arm. The force required to be applied on surface of water in the thicker arm to maintain equilibrium of wa is _____ N. [05 April, 2024 (Shift-I



9. Given below are two statements: one is labelled as Assertion and the other is labelled as Reason (R).
Assertion (A): When you squeeze one end of a tube to get toothpa out from the other end, Pascal's principle is observed.
Reason (R): A change in the pressure applied to an enclo incompressible fluid is transmitted undiminished to every port of the fluid and to the walls of its container.
In the light of the above statements, choose the most appropr answer from the options given below: [6 April, 2023 (Shift-
(a) A is not correct but R is correct
(b) A is correct but R is not correct
(c) Both A and R are correct and R is the correct explanation
(d) Both A and R are correct but R is NOT the correct explana of A

10. Given below are two statements:
Statement-I: Pressure in a reservoir of water is same at all po at the same level of water.
Statement-II: The pressure applied to enclosed water is transmi in all directions equally.

@IITJEE_NEET_CBSE

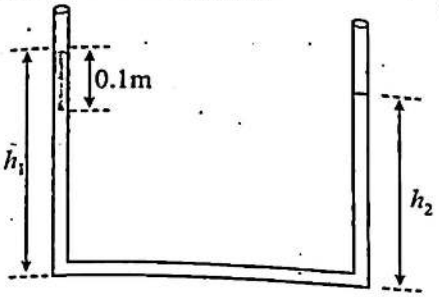
In the light of the above statements, choose the correct answer from the options given below: **[10 April, 2023 (Shift-I)]**

(a) Statement-I is false but Statement-II is true
(b) Both Statement-I and Statement-II are true
(c) Statement-I is true but Statement-II is false
(d) Both Statement-I and Statement-II are false

11. A pressure-pump has a horizontal tube of cross sectional area $10cm^2$ for the outflow of water at a speed of 20 m/s. The force exerted on the vertical wall just in front of the tube which stops water horizontally flowing out of the tube, is: [given: density of water = 1000 kg/m³] **[28 July, 2022 (Shift-II)]**

(a) 300 N (b) 500 N (c) 250 N (d) 400 N

12. An open-ended *U*-tube of uniform cross-sectional area contains water (density 10^3 kg m^{-3}). Initially the water level stands at 0.29 m from the bottom in each arm. Kerosene oil (a water-immiscible liquid) of density 800 kg m^{-3} is added to the left arm until its length is 0.1 m, as shown in the schematic figure below. The ratio $\left(\frac{h_1}{h_2}\right)$ of the heights of the liquid in the two arms is:

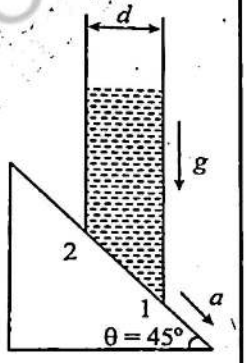


[JEE Adv, 2020]

(a) $\frac{15}{14}$ (b) $\frac{35}{33}$ (c) $\frac{7}{6}$ (d) $\frac{5}{4}$

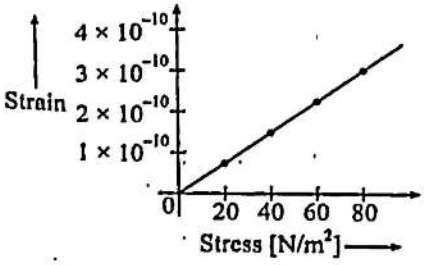
13. A hydraulic press can lift 100 kg when a mass '*m*' is placed on the smaller piston. It can lift_____ kg when the diameter of the larger piston is increased by 4 times and that of the smaller piston is decreased by 4 times keeping the same mass '*m*' on the smaller piston. **[24 Feb, 2021 (Shift-I)]**

14. A cylindrical tube, with its base as shown in the figure, is filled with water. It is moving down with a constant acceleration *a* along a fixed inclined plane with angle $\theta = 45°$. P_1 and P_2 are pressures at points 1 and 2, respectively, located at the base of the tube. Let $\beta = (P_1 - P_2)/(\rho g d)$, where ρ is density of water, *d* is the inner diameter of the tube and *g* is the acceleration due to gravity. Which of the following statement(s) is (are) correct? **[JEE Adv, 2021]**



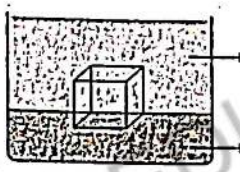
(a) $\beta = 0$ when $a = g/\sqrt{2}$
(b) $\beta > 0$ when $a = g/\sqrt{2}$
(c) $\beta = \frac{\sqrt{2}-1}{\sqrt{2}}$ when $a = g/2$
(d) $\beta = \frac{1}{\sqrt{2}}$ when

15. The elastic behaviour of material for linear stress and linear strain, is shown in the figure. The energy density for a linear strain of 5×10^{-4} is_____ kJ/m³. Assume that material is elastic upto the linear strain of 5×10^{-4}. **[26 June, 2022 (Shift-I)]**



T3 Archimedes Principle and Force of Buoyancy

16. A cube of ice floats partly in water and partly in kerosene oil. The ratio of volume of ice immersed in water to that in kerosene oil (specific gravity of Kerosene oil = 0.8, specific gravity of ice = 0.9) **[08 April, 2024 (Shift-II)]**



(a) 8 : 9 (b) 5 : 4 (c) 9 : 10 (d) 1 : 1

17. A sphere of relative density σ and diameter *D* has concentric cavity of diameter *d*. The ratio of *D*/*d*, if it just floats on water in a tank is: **[09 April, 2024 (Shift-I)]**

(a) $\left(\frac{\sigma}{\sigma-1}\right)^{1/3}$ (b) $\left(\frac{\sigma-1}{\sigma-1}\right)^{1/3}$
(c) $\left(\frac{\sigma-1}{\sigma}\right)^{1/3}$ (d) $\left(\frac{\sigma-2}{\sigma+2}\right)^{1/3}$

18. A tube of length 50 cm is filled completely with an incompressible liquid of mass 250 g closed both ends. The tube is then rotated in horizontal plane about one of its ends with a uniform angular velocity $x\sqrt{F}$ rad s^{-1}. If *F* be the force exerted by the liquid at the other end then the value of *x* will be _____. **[29 July, 2022 (Shift-II)]**

19. A hot air balloon is carrying some passengers, and a few sandbags of mass 1 kg each so that its total mass is 480 kg. Its effective volume giving the balloon its buoyancy is *V*. The balloon is floating at an equilibrium height of 100 m. When *N* number of sandbags are thrown out, the balloon rises to a new equilibrium height close to 150 m with its volume *V* remaining unchanged. If the variation of the density of air with height h from the ground is $\rho(h) = \rho_0 e^{\frac{h}{h_0}}$, where ρ_0=1.25 kg m^{-3} and h_0= 6000 m, the value of *N* is _____. **[JEE Adv, 2020]**

20. A small spherical droplet of density d is floating exactly half immerse in a liquid ρ and surface tension *T*. The radius of the droplet is (take note that the surface tension applies an upward force on the droplet): **[9 Jan, 2020 (Shift-II)]**

(a) $r = \sqrt{\frac{T}{(d+\rho)g}}$ (b) $r = \sqrt{\frac{3T}{(2d-\rho)g}}$
(c) $r = \sqrt{\frac{T}{(d-\rho)g}}$ (d) $r = \sqrt{\frac{2T}{3(d-\rho)g}}$

@RAJEDUNET

21. A hollow spherical shell at outer radius R floats just submerged under the water surface. The inner radius of the shell is r. If the specific gravity of the shell material is $\frac{27}{8}$ w.r.t water, the value of r is.
[5 Sep, 2020 (Shift-I)]

(a) $\frac{2}{3}R$ (b) $\frac{4}{9}R$ (c) $\frac{1}{3}R$ (d) $\frac{8}{9}R$

22. Consider a solid sphere of radius R and mass density $\rho(r) = \rho_0\left(1-\frac{r^2}{R^2}\right)$, $0 < r \le R$. The maximum density of a liquid in which it will float is

(a) $\frac{\rho_0}{5}$ (b) $\frac{2\rho_0}{5}$ (c) $\frac{2\rho_0}{3}$ (d) $\frac{\rho_0}{3}$

23. A leak proof cylinder of length 1m, made of a metal which has very low coefficient of expansion is floating vertically in water at 0°C such that its height above the water surface is 20 cm. When the temperature of water is increased to 4°C, the height of the cylinder above the water surface becomes 21 cm. The density of water at $T = 4°C$, relative to the density at $T = 0°C$ is close to:
[8 Jan, 2020 (Shift-I)]

(a) 1.0 (b) 1.04 (c) 1.26 (d) 1.01

24. A wooden block floating in a bucket of water has $\frac{4}{5}$ of its volume submerged. When certain amount of an oil is poured into the bucket, it is found that the block is just under the oil surface with half of its volume under water and half in oil. The density of oil relative to that of water is:
[9 April, 2019 (Shift-II)]

(a) 0.5 (b) 0.7 (c) 0.6 (d) 0.8

25. A cubical block of side 0.5 m floats on water with 30% of its volume under water. What is the maximum weight that can be put on the block without fully submerging it under water? (Take density of water = 10^3 kg/m^3)
[10 April, 2019 (Shift-II)]

(a) 65.4 kg (b) 87.5 kg
(c) 30.1 kg (d) 46.3 kg

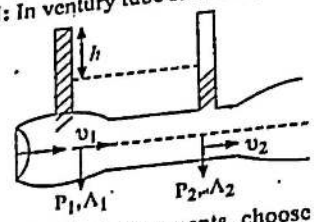
Continuity Equation, Bernoulli Theorem and Their Application

26. The reading of pressure metre attached with a closed pipe is 4.5×10^4 N/m^2. On opening the valve, water starts flowing and the reading of pressure metre falls to 2.0×10^4 N/m^2. The velocity of water is found to be $\sqrt{V}$ m/s. The value of V is _____.
[27 Jan, 2024 (Shift-II)]

27. In a test experiment on a model aeroplane in wind tunnel, the flow speeds on the upper and lower surfaces of the wings are 70 ms^{-1} and 65 ms^{-1} respectively. If the wing area is 2 m^2 the lift of the wing is _____ N. (Given density of air = 1.2 kg m^{-3})
[29 Jan, 2024 (Shift-I)]

28. A plane is in level flight at constant speed and each of its two wings has an area of 40 m^2. If the speed of the air is 180 km/h over the lower wing surface and 252 km/h over the upper wing surface, the mass of the plane is _____kg. (Take air density to be 1 kg m^{-3} and g = 10 ms^{-2})
[1 Feb, 2024 (Shift-I)]

29. Given below are two statements:
Statement I: When speed of liquid is zero everywhere, pressure difference at any two points depends on equation $P_1 - P_2 = \rho g(h_2 - h_1)$
Statement II: In ventury tube shown $2gh = v_1^2 - v_2^2$



In the light of the above statements, choose the most appropriate answer from the options given below.
[04 April, 2024 (Shift-I)]

(a) Both Statement I and Statement II are correct.
(b) Statement I is incorrect but Statement II is correct.
(c) Both Statement I and Statement II are incorrect.
(d) Statement I is correct but Statement II is incorrect.

30. Correct Bernoulli's equation is (symbols have their usual meaning)
[08 April, 2024 (Shift-I)]

(a) $P + mgh + \frac{1}{2}mv^2 = \text{constant}$

(b) $P + \rho gh + \frac{1}{2}\rho v^2 = \text{constant}$

(c) $P + \rho gh + \rho v^2 = \text{constant}$

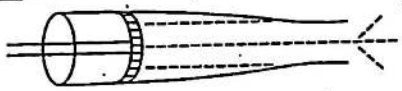
(d) $P + \frac{1}{2}\rho gh + \frac{1}{2}\rho v^2 = \text{constant}$

31. A fully loaded aircraft has a mass of 5.4×10^5 kg. Its total wing area is 500 m^2. It is in level flight with a speed of 1080 *km/h*. If the density of air is 1.2 kg m^{-3}, the fractional increase in the speed of the air on the upper surface of the wings relative to the lower surface in percentage will be ($g = 10$ *m/s*^{2})
[29 Jan, 2023 (Shift-II)]

(a) 16 (b) 6 (c) 8 (d) 10

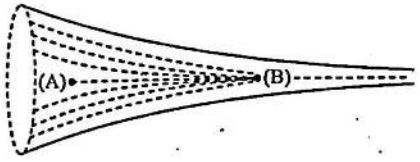
32. The surface of water in a water tank of cross section area 750 cm^2 on the top of a house is h *m* above the tap level. The speed of water coming out through the tap of cross section area 500 mm^2 is 30 cm/s. At that instant, $\frac{dh}{dt}$ is $x \times 10^{-3}$ *m/s*. The value of x will be _____.
[01 Feb 2023 (Shift-II)]

33. Figure below shows a liquid being pushed out of the tube by a piston having area of cross section 2.0 cm^2. The area of cross section at the outlet is 10 mm^2. If the piston is pushed at a speed of 4 cm s^{-1}, the speed of outgoing fluid is _____ cm s^{-1}.
[10 April, 2023 (Shift-II)]



34. Glycerine of density 1.25×10^3 kg m^{-3} is flowing through the conical section of pipe. The area of cross-section of the pipe at its ends is 10 cm^2 and 5 cm^2 and pressure drop across its length is 3 Nm^{-2}. The rate of flow of glycerine through the pipe is $x \times 10^{-5}$ m^3 s^{-1}. The value of x is _____.
[12 April, 2023 (Shift-I)]

35.

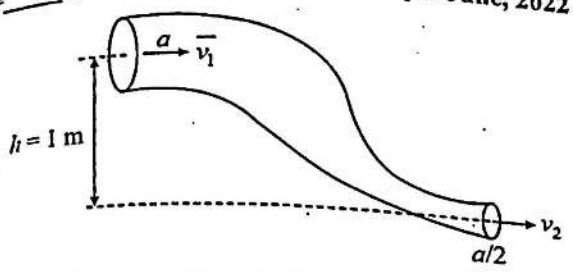


@TAKE_CBSE_@FREEDUNET

The figure shows a liquid of given density flowing steadily in horizontal tube of varying cross-section. Cross sectional areas at A is 1.5 cm^2 and B is 25 mm^2, if the speed of liquid at B is 60 cm/s then $(P_A - P_B)$ is:
(Given P_A and P_B are liquid pressures at A and B points.
Density $\rho = 1000\ kg\ m^{-3}$ A and B are on the axis of tube
[13 April, 2023 (Shift-I)]

(a) 175 Pa (b) 27 Pa (c) 135 Pa (d) 36 Pa

36. An ideal fluid of density 800 kgm^{-3}, flows smoothly through a bent pipe (as shown in figure) that tapers in cross-sectional area from a to $a/2$. The pressure difference between the wide and narrow sections of pipe is 4100 Pa. At wider section, the velocity of fluid is $\frac{\sqrt{x}}{6}$ ms^{-1} for $x =$ ____. (Given $g = 10\ ms^{-2}$) **[26 June, 2022 (Shift-I)]**



37. The area of cross-section of a large tank is 0.5 m^2 It has a narrow opening near the bottom having area of cross-section 1 cm^2 A load of 25 kg is applied on the water at the top in the tank. Neglecting the speed of water in the tank, the velocity of the water, coming out of the opening at the time when the height of water level in the tank is 40 cm above the bottom, will be _____ cms^{-1}.
[Take $g = 10\ ms^{-2}$] **[27 June, 2022 (Shift-I)]**

38. When a ball is dropped into a lake from a height 4.9 m above the water level, it hits the water with a velocity v and then sinks to the bottom with the constant velocity v. It reaches the bottom of the lake 4.0 s after it is dropped. The approximate depth of the lake is:
[27 June, 2022 (Shift-II)]

(a) 19.6 m (b) 29.4 m (c) 39.2 m (d) 73.5 m

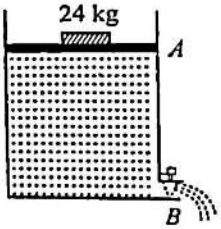
39. Water falls from a 40 m high dam at the rate of 9×10^4 kg per hour. Fifty percentage of gravitational potential energy can be converted into electrical energy. Using this hydro electric energy number of 100 W lamps, that can be lit, is:
(Take $g = 10\ ms^{-2}$) **[28 June, 2022 (Shift-II)]**

(a) 25 (b) 50 (c) 100 (d) 18

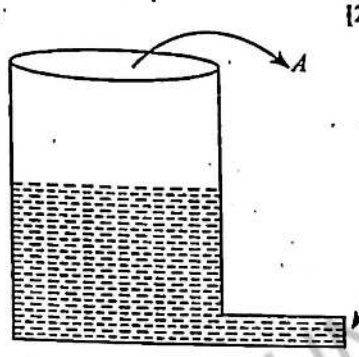
40. A liquid of density 750 kgm^{-3} flows smoothly through a horizontal pipe that tapers in cross-sectional area from $A_1 = 1.2 \times 10^{-2}\ m^2$ to $A_2 = \frac{A_1}{2}$. The pressure difference between the wide and narrow sections of the pipe is 4500 Pa. The rate of flow of liquid is _____ $\times 10^{-3} m^3 s^{-1}$. **[28 June, 2022 (Shift-II)]**

41. Consider a water tank as shown in the figure. It's cross-sectional area is 0.4 m^2. The tank has an opening B near the bottom whose cross-sectional area is 1 cm^2. A load of 24 kg is applied on the water at the top when the height of the water level is 40 cm above the bottom, the velocity of water coming out the opening B is $v\ ms^{-1}$.

The value of v, to the nearest integer, is _____ [Take value of g to be $10\ ms^{-2}$] **[18 March, 2021 (Shift-II)]**



42. A light cylindrical vessel is kept on a horizontal surface. Area of base is A. A hole of cross-sectional area 'a' is made just at its bottom side. The minimum coefficient of friction necessary to prevent sliding the vessel due to the impact force of the emerging liquid is ($a << A$):
[27 July, 2021 (Shift-I)]



(a) None of these (b) $\frac{2a}{A}$

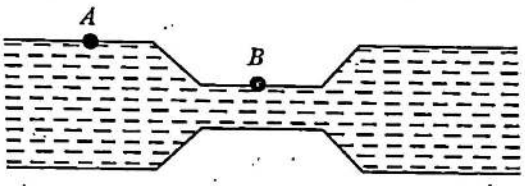
(c) $\frac{A}{2a}$ (d) $\frac{a}{A}$

43. The water is filled up to height of 12 m in a tank having vertical sidewalls. A hole is made in one of the walls at a depth 'h' below the water level. The value of 'h' for which the emerging steam of water strikes the ground at the maximum range is _____ m.
[27 July, 2021 (Shift-II)]

44. An ideal fluid flows (laminar flow) through a pipe of non-uniform diameter. The maximum and minimum diameters of the pipes are 6.4 cm and 4.8 cm, respectively. The ratio of the minimum and the maximum velocities of fluid in this pipe is:
[7 Jan, 2020 (Shift-II)]

(a) $\frac{3}{4}$ (b) $\frac{81}{256}$ (c) $\frac{\sqrt{3}}{2}$ (d) $\frac{9}{16}$

45. Water flows in a horizontal tube (see figure). The pressure of water changes by 700 Nm^{-2} between A and B where the area of cross section are 40 cm^2 and 20 cm^2, respectively. Find the rate of flow of water through the tube. (density of water = 1000 kg m^{-3})
[9 Jan, 2020 (Shift-I)]



(a) 1810 cm^3/s (b) 2420 cm^3/s
(c) 2720 cm^3/s (d) 3020 cm^3/s

46. Two identical cylindrical vessels are kept on the ground and each contain the same liquid of density d. The area of the base of both vessels is S but the height of liquid in one vessel is x_1 and in the other, x_2. When both cylinders are connected through a pipe of negligible volume very close to the bottom, the liquid flows from one vessel to

@FAKE_CODER_@RAJ_EDUNET

the other until it comes to equilibrium at a new height. The change in energy of the system in the process is: [4 Sep, 2020 (Shift-II)]

(a) $\frac{3}{4}gdS(x_2-x_1)^2$ (b) $gdS(x_2+x_1)^2$

(c) $\frac{1}{4}gdS(x_2-x_1)^2$ (d) $gdS(x_2^2+x_1^2)$

47. A fluid is flowing through a horizontal pipe of varying cross-section, with speed $v\ ms^{-1}$ at a point where the pressure is P Pascal. At another point where pressure is $\frac{P}{2}$ Pascal its speed is $V\ ms^{-1}$. If the density of the fluid is ρ kg m^{-3} and the flow is streamline, then V is equal to: [6 Sep, 2020 (Shift-II)]

(a) $\sqrt{\frac{P}{p}+v}$ (b) $\sqrt{\frac{2P}{p}+v^2}$

(c) $\sqrt{\frac{P}{2p}+v^2}$ (d) $\sqrt{\frac{P}{p}+v^2}$

48. A train with cross-sectional area S_t is moving with speed v_t inside a long tunnel of cross-sectional area $S_0(S_0 = 4S_t)$. Assume that almost all the air (density ρ) in front of the train flows back between its sides and the walls of the tunnel. Also, the air flow with respect to the train is steady and laminar. Take the ambient pressure and that inside the train to be p_0. If the pressure in the region between the sides of the train and the tunnel walls is p, then $p_0 - p = \frac{7}{2N}\rho v_t^2$. The value of N is _____. [JEE Adv, 2020]

49. The top of a water tank is open to air and its water level is maintained. It is giving out 0.74 m^3 water per minute through a circular opening of 2 cm radius in its wall. The depth of the centre of the opening from the level of water in the tank is close to: [9 Jan, 2019 (Shift-II)]

(a) 6.0 m (b) 4.8 m
(c) 9.6 m (d) 2.9 m

50. Water flows into a large tank with flat bottom at the rate of $10^{-4}\ m^3s^{-1}$. Water is also leaking out of a hole of area 1 cm^2 at its bottom. If the height of the water in the tank remains steady, then this height is: [10 Jan, 2019 (Shift-I)]

(a) 5.1 cm (b) 1.7 cm
(c) 4 cm (d) 2.9 cm

51. Water from a tap emerges vertically downwards with an initial speed of 1.0 ms^{-1}. The cross sectional area of the tap is $10^{-4}m^2$. Assume that the pressure is constant throughout the stream of water and that the flow is streamlined. The cross-sectional area of the stream, 0.15 m below the tap would be: (Take $g = 10\ ms^{-2}$) [10 April, 2019 (Shift-II)]

(a) $1 \times 10^{-5}\ m^2$ (b) $5 \times 10^{-5}\ m^2$
(c) $2 \times 10^{-5}\ m^2$ (d) $5 \times 10^{-4}\ m^2$

52. A liquid of density ρ is coming out of a hose pipe of radius a with horizontal speed v and hits a mesh. 50% of the liquid passes through the mesh unaffected. 25% looses all of its momentum and 25% comes back with the same speed. The resultant pressure on the mesh will be: [11 Jan, 2019 (Shift-I)]

(a) $\frac{1}{4}\rho v^2$ (b) $\frac{3}{4}\rho v^2$

(c) $\frac{1}{2}\rho v^2$ (d) ρv^2

Surface Tension, Surface Energy

53. A small liquid drop of radius R is divided into 27 identical liquid drops. If the surface tension is T, then the work done in the process will be: [29 Jan, 2024 (Shift-II)]

(a) $8\pi R^2T$ (b) $3\pi R^2T$

(c) $\frac{1}{8}\pi R^2T$ (d) $4\pi R^2T$

54. A big drop is formed by coalescing 1000 small identical drops of water. If E_1 be the total surface energy of 1000 small drops of water and E_2 be the surface energy of single big drop of water, the $E_1 : E_2$ is $x : 1$ where $x =$ _____. [30 Jan, 2024 (Shift-II)]

55. A big drop is formed by coalescing 1000 small droplets of water. The surface energy will become: [1 Feb, 2024 (Shift-I)]

(a) 100 times (b) 10 times

(c) $\frac{1}{10}th$ (d) $\frac{1}{10}th$

56. A soap bubble is blown to a diameter of 7 cm. 36960 erg of work is done in blowing it further. If surface tension of soap solution is 40 dyne/cm then the new radius is _____ cm. Take : $\left(\pi = \frac{22}{7}\right)$ [04 April, 2024 (Shift-I)]

57. A big drop is formed by coalescing 1000 small droplets of water. The ratio of surface energy of 1000 droplets to that of energy of big drop is $\frac{10}{x}$. The value of x is _____. [06 April, 2024 (Shift-I)]

58. Pressure inside a soap bubble is greater than the pressure outside by an amount: [06 April, 2024 (Shift-II)]

(given : R = Radius of bubble, S = Surface tension of bubble)

(a) $\frac{4S}{R}$ (b) $\frac{4R}{S}$ (c) $\frac{S}{R}$ (d) $\frac{2S}{R}$

59. A liquid column of height 0.04 cm balances excess pressure of soap bubble of certain radius. If density of liquid is $8 \times 10^3\ kg\ m^{-3}$ and surface tension of soap solution is $0.28\ Nm^{-1}$, then diameter of the soap bubble is _____cm. (if $g = 10\ ms^{-2}$) [08 April, 2024 (Shift-I)]

60. The excess pressure inside a soap bubble is thrice the excess pressure inside a second soap bubble. The ratio between the volume of the first and the second bubble is: [09 April, 2024 (Shift-II)]

(a) 1 : 9 (b) 1 : 3
(c) 1 : 81 (d) 1 : 27

61. A spherical drop of liquid splits into 1000 identical spherical drops. If μ_i is the surface eenergy of the original drop and μ_f is the total surface energy of the resulting drops, then (ignoring evaporation) $\frac{u_f}{u_i} = \left(\frac{10}{x}\right)$. Then value of x is _____. [25 Jan, 2023 (Shift-II)]

62. Surface tension of a soap bubble is $2.0 \times 10^{-2}\ Nm^{-1}$. Work done to increase the radius of soap bubble from 3.5 *cm* to 7 *cm* will be: [Use $\pi = \frac{22}{7}$] [29 Jan, 2023 (Shift-I)]

(a) $0.72 \times 10^{-4}\ J$ (b) $5.76 \times 10^{-4}\ J$
(c) $18.48 \times 10^{-4}\ J$ (d) $9.24 \times 10^{-4}\ J$

@JEE_CODEX@RAJEDUNET

63. If 1000 droplets of water of surface tension 0.07 N/m having same radius 1 mm each, combine to form a single drop. In the process the released surface energy is:

$\left(\text{Take } \pi = \frac{22}{7}\right)$ **[31 Jan, 2023 (Shift-I)]**

(a) 7.92×10^{-6} J (b) 7.92×10^{-4} J
(c) 9.68×10^{-4} J (d) 8.8×10^{-5} J

64. A mercury drop of radius 10^{-3} m is broken into 125 equal size droplets. Surface tension of mercury is 0.45 Nm^{-1}. The gain in surface energy is: **[01 Feb 2023 (Shift-I)]**

(a) 2.26×10^{-5} J (b) 28×10^{-5} J
(c) 17.5×10^{-5} J (d) 5×10^{-5} J

65. The surface tension of soap solution is 3.5×10^{-2} Nm^{-1}. The amount of work done required to increase the radius of soap bubble from 10 cm to 20 cm is ____ $\times 10^{-4}$J. **[11 April, 2023 (Shift-II)]**

66. There is an air bubble of radius 1.0 mm in a liquid of surface tension 0.075 Nm^{-1} and density 1000 kg m^{-3} at a depth of 10 cm below the free surface. The amount by which the pressure inside the bubble is greater than the atmospheric pressure is _____ Pa ($g = 10$ ms^{-2}) **[15 April, 2023 (Shift-I)]**

67. A water drop of diameter 2 cm is broken into 64 equal droplets. The surface tension of water is 0.075 N/m. In this process the gain in surface energy will be: **[28 June, 2022 (Shift-I)]**

(a) 2.8×10^{-4} J (b) 1.5×10^{-3} J
(c) 1.9×10^{-4} J (d) 9.4×10^{-5} J

68. A drop of liquid of density ρ is floating half immersed in a liquid of density σ and surface tension 7.5×10^{-4} Ncm^{-1}. The radius of drop in cm will be: ($g = 10$ ms^{-2}) **[25 July, 2022 (Shift-II)]**

(a) $\frac{15}{\sqrt{2\rho - \sigma}}$ (b) $\frac{15}{\sqrt{\rho - \sigma}}$

(c) $\frac{3}{2\sqrt{\rho - \sigma}}$ (d) $\frac{3}{20\sqrt{2\rho - \sigma}}$

69. A water drop of radius 1 cm is broken into 729 equal droplets. If surface tension of water is 75 dyne /cm, then the gain in surface energy upto first decimal place will be:
(Given $\pi = 3.14$) **[26 July, 2022 (Shift-I)]**

(a) 8.5×10^{-4} J (b) 8.2×10^{-4} J
(c) 7.5×10^{-4} J (d) 5.3×10^{-4} J

70. A large number of water drops, each of radius r, combine to have a drop of radius R. If the surface tension is T and mechanical equivalent of heat is J, the rise in heat energy per unit volume will be: **[26 Feb, 2021 (Shift-I)]**

(a) $\frac{3T}{J}\left(\frac{1}{r} - \frac{1}{R}\right)$ (b) $\frac{2T}{rJ}$

(c) $\frac{3T}{rJ}$ (d) $\frac{2T}{J}\left(\frac{1}{r} - \frac{1}{R}\right)$

71. Two small drops of mercury each of radius R coalesce to from a single large drop. The ratio of total surface energy before and after the change is: **[20 July, 2021 (Shift-II)]**

(a) $2^{\frac{1}{3}} : 1$ (b) $1 : 2^{\frac{1}{3}}$
(c) $2 : 1$ (d) $1 : 2$

72. Two narrow bores of diameter 5.0 mm and 8.0 mm are joined together to form a U-shaped tube open at both ends. If this U-tube contains water, what is the difference in the level of two limbs of the tube.

[Take surface tension of water $T = 7.3 \times 10^{-2}$ Nm^{-1}, angle of contact = 0, $g = 10$ ms^{-2} and density of water = 1.0×10^3 kgm^{-3}] **[26 Aug, 2021 (Shift-I)]**

(a) 2.19 mm (b) 4.97 mm (c) 5.34 mm (d) 3.62 mm

73. When water is filled carefully in a glass, one can fill it to a height h above the rim of the glass due to the surface tension of water. To calculate h just before water starts flowing, model the shape of the water above the rim as a disc of thickness h having semicircular edges, as shown schematically in the figure. When the pressure of water at the bottom of this disc exceeds what can be withstood due to the surface tension, the water surface breaks near the rim and water starts flowing from there. If the density of water, its surface tension and the acceleration due to gravity are 10^3 kg m^{-3}, 0.07 Nm^{-1} and 10 ms^{-2}, respectively, the value of h (in mm) is _____. **[JEE Adv, 2020]**

Capillary Rise

74. Given below are two statements: **[29 Jan, 2024 (Shift-I)]**

Statement-I: If a capillary tube is immersed first in cold water and then in hot water, the height of capillary rise will be smaller in hot water.

Statement-II: If a capillary tube is immersed first in cold water and then in hot water, the height of capillary rise will be smaller in cold water.

In the light of the above statements, choose the most appropriate from the options given below

(a) Both Statement-I and Statement-II are true
(b) Both Statement-I and Statement-II are false
(c) Statement-I is true but Statement-II is false
(d) Statement-I is false but Statement-II is true

75. Given below are two statements:

Statement I: The contact angle between a solid and a liquid is a property of the material of the solid and liquid as well.

Statement II: The rise of a liquid in a capillary tube does not depend on the inner radius of the tube.

In the light of the above statements, choose the correct answer from the options given below: **[04 April, 2024 (Shift-II)]**

(a) Both Statement I and Statement II are false
(b) Statement I is false but Statement II is true.
(c) Statement I is true but Statement II is false.
(d) Both Statement I and Statement II are true.

76. Given below are two statements :

Statement-I: When a capillary tube is dipped into a liquid, the liquid neither rises nor falls in the capillary. The contact angle may be 0°.

Statement-II: The contact angle between a solid and a liquid is a property of the material of the solid and liquid as well:

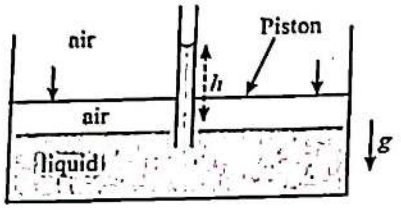
In the light of above statement, choose the correct answer from the options given below. **[05 April, 2024 (Shift-I)]**

(a) **Statement-I** is false but **Statement-II** is true.
(b) Both **Statement-I** and **Statement-II** are true.
(c) Both **Statement-I** and **Statement-II** are false.
(d) **Statement-I** is true and **Statement-II** is false.

@FAKE_COURSE_X_GRAVITY_EDUNET

77. An incompressible liquid is kept in a container having a weightless piston with a hole. A capillary tube of inner radius 0.1 mm is dipped vertically into the liquid through the airtight piston hole, as shown in the figure. The air in the container is isothermally compressed from its original volume $\frac{100}{101}V_0$ with the movable piston. Considering 'air' as an ideal gas, the height (h) of the liquid column in the capillary above the liquid level in cm is_____.

[Given: Surface tension of the liquid is 0.075 Nm^{-1}, atmospheric pressure is 10^5 Nm^{-2}, acceleration due to gravity (g) is 10 ms^{-2}, density of the liquid is 10^3 $kg\,m^{-3}$ and contact angle of capillary surface with the liquid is zero] [JEE Adv, 2023]



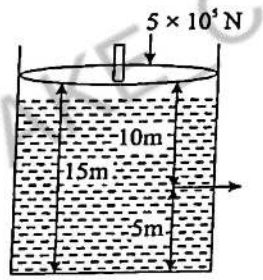
78. The height of liquid column raised in a capillary tube of certain radius when dipped in liquid A vertically is, 5 cm. If the tube is dipped in a similar manner in another liquid B of surface tension and density double the values of liquid A, the height of liquid column raised in liquid B would be_____ m.

[30 Jan, 2023 (Shift-I)]

(a) 0.20 (b) 0.5 (c) 0.05 (d) 0.10

79. Consider a cylindrical tank of radius 1m is filled with water. The top surface of water is at 15 m from the bottom of the cylinder. There is a hole on the wall of cylinder at a height of 5 m from the bottom. A force of 5×10^5N is applied on the top surface of water using a piston. The speed of efflux from the hole will be:
(given atmospheric pressure $P_A = 1.01 \times 10^5$ Pa, density of water ρ_w = 1000kg /m^3 and gravitational acceleration g = 10m/ s^2)

[28 July, 2022 (Shift-II)]

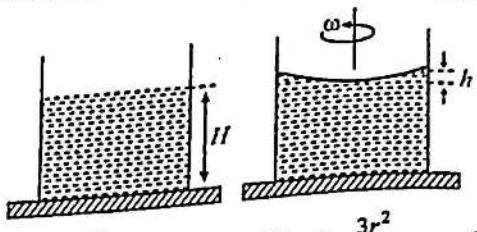


(a) 11.6 m/s (b) 10.8 m/s (c) 17.8 m/s (d) 14.4 m/s

80. A capillary tube made of glass of radius 0.15 mm is dipped vertically in a beaker filled with methylene iodide (surface tension = 0.05 Nm^{-1}, density = 667 kg m^{-3}) which rises to height h in the tube. It is observed that the two tangents drawn from liquid-glass interfaces (from opp. sides of the capillary) make an angle of 60° with one another. Then h is close to ($g = 10$ ms^{-2}) [2 Sep, 2020 (Shift-II)]

(a) 0.049 m (b) 0.087 m (c) 0.137 m (d) 0.172 m

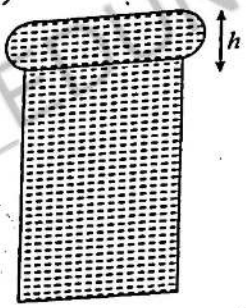
81. A beaker of radius r is filled with water (refractive index $\frac{4}{3}$) up to a height H as shown in the figure on the left. The beaker is kept on a horizontal table rotating with angular speed ω. This makes the water surface curved so that the difference in the height of water level at the center and at the circumference of the beaker is h ($h << H$, $h << r$), as shown in the figure on the right. Take this surface to be approximately spherical with a radius of curvature R. Which of the following is/are correct?
(g is the acceleration due to gravity) [JEE Adv, 2020]



(a) $R = \frac{h^2 + r^2}{2h}$ (b) $R = \frac{3r^2}{2h}$

(c) Apparent depth of the bottom of the beaker is close to $\frac{3H}{2}\left(1+\frac{\omega^2 H}{2g}\right)^{-1}$

(d) Apparent depth of the bottom of the beaker is close to $\frac{3H}{4}\left(1+\frac{\omega^2 H}{4g}\right)^{-1}$



82. In an experiment to verify Stokes law, a small spherical ball of radius r and density ρ falls under gravity through a distance h in air before entering a tank of water. If the terminal velocity of the ball inside water is same as its velocity just before entering the water surface, then the value of h is proportional to (ignore viscosity of air)

[5 Sep, 2020 (Shift-II)]

(a) r^4 (b) r^3 (c) r (d) r^2

83. If 'M' is the mass of water that rises in a capillary tube of radius 'r', then mass of water which will rise in a capillary tube of radius '$2r$' is: [9 April, 2019 (Shift-I)]

(a) 4 M (b) $\frac{M}{2}$ (c) M (d) 2 M

84. The ratio of surface tensions of mercury and water is given to be 7.5 while the ratio of their densities is 13.6. Their contact angles, with glass, are close to 135° and 0°, respectively. It is observed that mercury gets depressed by an amount h in a capillary tube of radius r_1, while water rises by the same amount h in a capillary tube of radius r_2. The ratio, (r_1/r_2), is then close to:

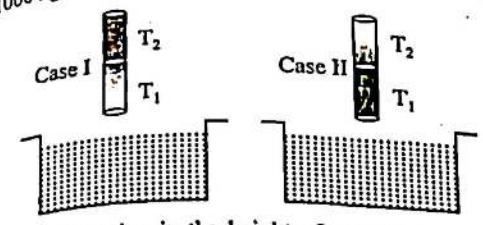
[10 April, 2019 (Shift-I)]

(a) 3/5 (b) 4/5 (c) 2/3 (d) 2/5

85. A cylindrical capillary tube of 0.2 mm radius is made by joining two capillaries T_1 and T_2 of different materials having water contact angles of 0° and 60°, respectively. The capillary tube is dipped vertically in water in two different configurations, case I and II as

@FAKE_CBT_X@RAJ_PHYSNET

shown in figure. Which of the following option(s) is(are) correct? (Surface tension of water = 0.075 N/m, density of water = 1000 kg/m³, take $g = 10 m/s^2$) [JEE Adv, 2019]



(a) The correction in the height of water column raised in the tube, due to weight of water contained in the meniscus, will be different for both cases.

(b) For case I, if the capillary joint is 5 cm above the water surface, the height of water column raised in the tube will be more than 8.75 cm. (Neglect the weight of the water in the meniscus)

(c) For case I, if the joint is kept at 8 cm above the water surface, the height of water column in the tube will be 7.5 cm. (Neglect the weight of the water in the meniscus)

(d) For case II, if the capillary joint is 5 cm above the water surface, the height of water column raised in the tube will be 3.75 cm. (Neglect the weight of the water in the meniscus)

Excess Pressure in Drop and Bubble

86. A spherical soap bubble of radius 3 cm is formed inside another spherical soap bubble of radius 6 cm. If the internal pressure of the smaller bubble of radius 3 cm in the above system is equal to the internal pressure of the another single soap bubble of radius r cm.

The value of r is _____. [27 July, 2022 (Shift-II)]

87. Given below are two statements: One is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A): Clothes containing oil or grease stains cannot be cleaned by water wash.

Reason (R): Because the angle of contact between the oil/ grease and water is obtuse. In the light of the above statements, choose the correct answer from the option given below.

[29 July, 2022 (Shift-I)]

(a) Both (A) and (R) are true and (R) is the correct explanation of (A)

(b) Both (A) and (R) are true but (R) is not the correct explanation of (A)

(c) (A) is true but (R) is false

(d) (A) is true but (R) is true

88. When two soap bubbles of radii a and b ($b > a$) coalesce, the radius of curvature of common surface is:

[17 March, 2021 (Shift-I)]

(a) $\frac{ab}{a+b}$ (b) $\frac{ab}{b-a}$

(c) $\frac{b-a}{ab}$ (d) $\frac{a+b}{ab}$

89. Suppose you have taken a dilute solution of oleic acid in such a way that its concentration becomes 0.01 cm³ of oleic acid per cm³ of the solution. Then you make a thin film of this solution (monomolecular thickness) of area 4 cm² by considering 100 spherical drops of radius $\left(\frac{3}{40\pi}\right)^{\frac{1}{3}} \times 10^{-3}$ cm. Then the thickness of oleic acid Layer will be $x \times 10^{-14}$ m. Where x is _____. [17 March, 2021 (Shift-II)]

90. A soap bubble of radius 3 cm is formed inside the another soap bubble of radius 6 cm. The radius of an equivalent soap bubble which has the same excess pressure as inside the smaller bubble with respect to the atmospheric pressure is _____ cm.

[26 Aug, 2021 (Shift-I)]

91. Pressure inside two soap bubbles are 1.01 atm and 1.02 atm, respectively. The ratio of their volumes is:

[3 Sep, 2020 (Shift-I)]

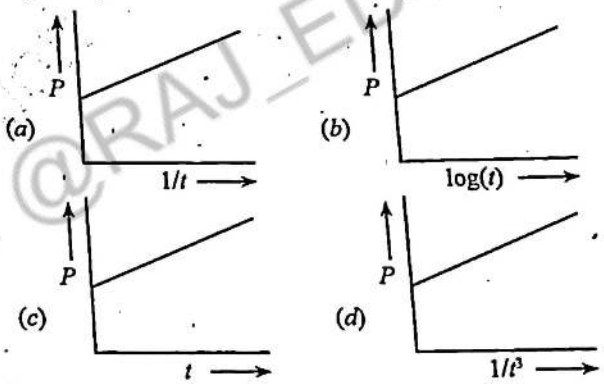
(a) 2 : 1 (b) 0.8 : 1 (c) 4 : 1 (d) 8 : 1

92. A air bubble of radius 1 cm in water has an upward acceleration 9.8 cm s^{-2}. The density of water is 1 gm cm^{-3} and water offers negligible drag force on the bubble. The mass of the bubble is ($g = 980$ cm/s²)

[4 Sep, 2020 (Shift-I)]

(a) 1.52 gm (b) 4.51 gm (c) 3.15 gm (d) 4.15 gm

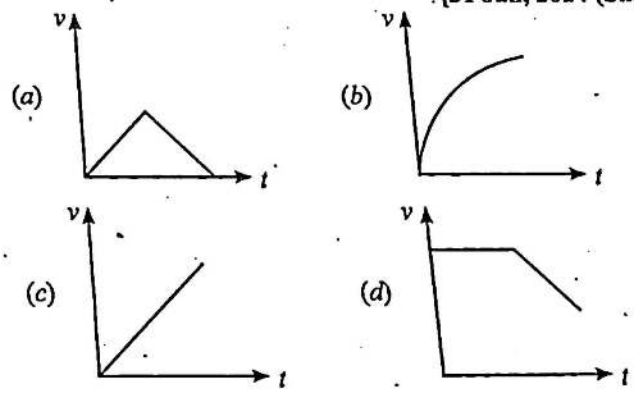
93. A soap bubble, blown by a mechanical pump at the mouth of a tube, increases in volume, with time, at a constant rate. The graph that correctly depicts the time dependence of pressure inside the bubble is given by: [12 Jan, 2019 (Shift-II)]



Viscosity and Viscous Force

94. A small steel ball is dropped into a long cylinder containing glycerine. Which one of the following is the correct representation of the velocity time graph for the transit of the ball?

[31 Jan, 2024 (Shift-I)]



@FAKE_CBSE_X @RAJ_EDUCATION

95. Given below are two statements: [27 Jan, 2024 (Shift-I)]

Statement-I: Viscosity of gases is greater than that of liquids.

Statement-II: Surface tension of a liquid decreases due to the presence of insoluble impurities.

In the light of the above statements, choose the most appropriate answer from the options given below:

(a) Statement-I is correct but statement-II is incorrect
(b) Statement-I is incorrect but Statement-II is correct
(c) Both Statement-I and Statement-II are incorrect
(d) Both Statement-I and Statement-II are correct

96. A small spherical ball of radius r, falling through a viscous medium of negligible density has terminal velocity 'v'. Another ball of the same mass but of radius 2r, falling through the same viscous medium will have terminal velocity: [31 Jan, 2024 (Shift-II)]

(a) $\frac{v}{2}$ (b) $\frac{v}{4}$ (c) 4v (d) 2v

97. A small ball of mass m and density ρ is dropped in a viscous liquid of density ρ_0. After sometime, the ball falls with constant velocity. The viscous force on the ball is: [06 April, 2024 (Shift-I)]

(a) $mg\left(\frac{\rho_0}{\rho}-1\right)$ (b) $mg\left(1+\frac{\rho}{\rho_0}\right)$

(c) $mg(1-\rho\rho_0)$ (d) $mg\left(1-\frac{\rho_0}{\rho}\right)$

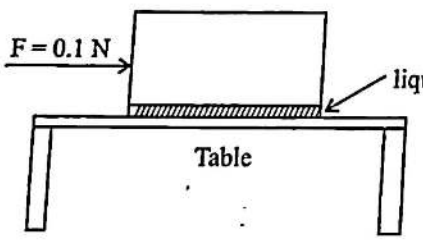
98. Small water droplets of radius 0.01 mm are formed in the upper atmosphere and falling with a terminal velocity of 10 cm/s. Due to condensation, if 8 such droplets are coalesced and formed a larger drop, the new terminal velocity will be .....cm/s. [08 April, 2024 (Shift-II)]

99. A spherical ball of radius 1×10^{-4} m and density 10^5 kg/m³ falls freely under gravity through a distance *h* before entering a tank of water. If after entering in water the velocity of the ball does not change, then the value of h is approximately :
(The coefficient of viscosity of water is 9.8×10^{-6} Ns/m²) [09 April, 2024 (Shift-II)]

(a) 2296 m (b) 2249 m
(c) 2518 m (d) 2396 m

100. A spherical ball of radius 1 *mm* and density 10.5 *g/cc* is dropped in glycerine of coefficient of viscosity 9.8 poise and density 1.5 *g/cc*. Viscous force on the ball when it attains constant velocity is $3696\times10^{-x}N$. The value of *x* is_____. [24 Jan, 2023 (Shift-II)]
(Given, $g=9.8m/s^2$ and $\pi=\frac{22}{7}$)

101. A metal block of base area 0.20 m² is placed on a table, as shown in the figure. A liquid film of thickness 0.25 mm is inserted between the block and the table. The block is pushed by a horizontal force of 0.1 N and moves with a constant speed. If the viscosity of the liquid is 5.0×10^{-3} *Pl*, the speed of the block is _____ $\times10^{-3}$ *m/s*. [29 Jan, 2023 (Shift-II)]



102. A small ball of mass *M* and density ρ is dropped in a viscous liquid of density ρ_0. After some time, the ball falls with a constant velocity. What is the viscous force on the ball ? [6 April, 2023 (Shift-I)]

(a) $F=Mg\left(1-\frac{\rho_0}{\rho}\right)$ (b) $F=Mg\left(1+\frac{\rho}{\rho_0}\right)$

(c) $F=Mg\left(1+\frac{\rho_0}{\rho}\right)$ (d) $F=Mg(1\pm\rho\rho_0)$

103. An air bubble of diameter 6 mm rises steadily through a solution of density 1750 kg/m³ at the rate of 0.35 cm/s. The co-efficient of viscosity of the solution (neglect density of air) is ___ Pas (given, g = 10 ms^{-2}) [8 April, 2023 (Shift-I)]

104. Match List-I with List-II [8 April, 2023 (Shift-II)]

LIST-I	LIST-II
A. Torque	I. $ML^{-2}T^{-2}$
B. Stress	II. ML^2T^{-2}
C. Pressure gradient	III. $ML^{-1}T^{-1}$
D. Coefficient of viscosity	IV. $ML^{-1}T^{-2}$

Choose the correct answer from the options given below:
(a) A-III, B-IV, C-I, D-II (b) A-IV, B-II, C-III, D-I
(c) A-II, B-IV, C-I, D-III (d) A-II, B-I, C-IV, D-III

105. Eight equal drops of water are falling through air with a steady speed of 10 cm/s. If the drops coalesce, the new velocity is: [11 April, 2023 (Shift-II)]

(a) 10 cm/s (b) 40 cm/s (c) 16 cm/s (d) 5 cm/s

106. The terminal velocity (v_t) of the spherical rain drop depends on the radius (*r*) of the spherical rain drop as: [25 June, 2022 (Shift-I)]

(a) $r^{1/2}$ (b) r (c) r^2 (d) r^3

107. The velocity of upper layer of water in a river is 36 kmh⁻¹. Shearing stress between horizontal layers of water is 10^{-3} Nm⁻². Depth of the river is _____ m. (Co-efficient of viscosity of water is 10^{-2} Pa.s) [25 June, 2022 (Shift-I)]

108. The velocity of a small ball of mass '*m*' and density d_1 when dropped in a container filled with glycerine, becomes constant after some time. If the density of glycerine is d_2, then the viscous force acting on the ball, will be: [27 June, 2022 (Shift-I)]

(a) $mg\left(1-\frac{d_1}{d_2}\right)$ (b) $mg\left(1-\frac{d_2}{d_1}\right)$

(c) $mg\left(\frac{d_1}{d_2}-1\right)$ (d) $mg\left(\frac{d_2}{d_1}-1\right)$

109. Given below are two statements: One is labelled as **Assertion A** and the other is labelled as **Reason R**.

Assertion A: Product of Pressure (P) and time (t) has the same dimension as that of coefficient of viscosity.

Reason R: Coefficient of viscosity = $\frac{\text{Force}}{\text{Velocity gradient}}$

Choose the correct answer from the options given below: [28 June, 2022 (Shift-I)]

(a) Both A and R true, and R is correct explanation of A.
(b) Both A and R are true but R is NOT the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

@MAKE OUR CAREER EDUNET

110. A water drop of radius 1 μm falls in a situation where the effect of buoyant force is negligible. Co-efficient of viscosity of air is 1.8×10^{-5} Nsm^{-2} and its density is negligible as compared to that of water 10^6 gm^{-3}. Terminal velocity of the water drop is:

[28 June, 2022 (Shift-II)]

(Take acceleration due to gravity = 10 ms^{-2})

(a) 145.4×10^{-6} ms^{-1} (b) 118.0×10^{-6} ms^{-1}

(c) 132.6×10^{-6} ms^{-1} (d) 123.4×10^{-6} ms^{-1}

111. A small spherical ball of radius 0.1 mm and density 10^4 kgm^{-3} falls freely under gravity through a distance h before entering a tank of water. If, after entering the water the velocity inside water, then the value of h will be _____m. [29 June, 2022 (Shift-II)]

(Given g = 10 ms^{-2}, viscosity of water = 1.0×10^{-5} $N\text{-}sm^{-2}$).

112. The diameter of an air bubble which was initially 2mm, rises steadily through a solution of density 1750 kgm^{-3} at the rate of 0.35 cms^{-1}. The coefficient of viscosity of the solution is _____ poise (in nearest integer). (The density of air is negligible).

[28 July, 2022 (Shift-I)]

113. The velocity of a small ball of mass 0.3g and density 8g/cc when dropped in a container filled with glycerine becomes constant after some time. If the density of glycerine is 1.3 g/cc, then the value of viscous force acting on the ball will be $x \times 10^{-4}$ N, value of x is _____ [use g = 10 m/s^2] [29 July, 2022 (Shift-II)]

114. A raindrop with radius R = 0.2 mm falls from a cloud at a height h = 2000 m above the ground. Assume that the drop is spherical through its fall and the force of buoyance may be neglected, then the terminal speed attained by the raindrop is:

[27 July, 2021 (Shift-II)]

[Density of water ρ_w = 1000 kgm^{-3} and Density of air ρ_a = 1.2 kg^{-3}, g = 10 m/s^2

Coefficient of viscosity of air = 1.8×10^{-5} Nsm^{-2}]

(a) 4.94 ms^{-1} (b) 14.4 ms^{-1}

(c) 43.56 ms^{-1} (d) 250.6 ms^{-1}

115. In Millikan's oil drop experiment, what is viscous force acting on an uncharged drop of radius 2.0×10^{-5} and density 1.2×10^3 kgm^{-3}? Take viscosity of liquid = 1.8×10^{-5} Nsm^{-2}. (Neglect buoyancy due to air). [27 Aug, 2021 (Shift-I)]

(a) 5.8×10^{-10} N (b) 1.8×10^{-10} N

(c) 3.8×10^{-10} N (d) 3.9×10^{-10} N

116. As shown schematically in the figure, two vessels contain water solutions (at temperature T) of potassium permanganate ($KMnO_4$) of different concentrations n_1 and n_2 ($n_1 > n_2$) molecules per unit volume with $\Delta n = (n_1 - n_2) << n_1$. When they are connected by a tube of small length ℓ and cross-sectional area S, $KMnO_4$ starts to diffuse from the left to the right vessel through the tube. Consider the collection of molecules to behave as dilute ideal gases and the difference in their partial pressure in the two vessels causing the diffusion. The speed v of the molecules is limited by the viscous force $-\beta v$ on each molecule, where β is a constant. Neglecting all terms of the order $(\Delta n)^2$, which of the following is/are correct? (k_B is the Boltzmann constant): [JEE Adv, 2020]

(a) The force causing the molecules to move across the tube is $\Delta n k_B T S$

(b) Force balance implies $n_1 \beta v \ell = \Delta n k_B T$

(c) Total number of molecules going across the tube per sec is $\left(\frac{\Delta n}{\ell}\right)\left(\frac{k_B T}{\beta}\right)S$

(d) Rate of molecules getting transferred through the tube does not change with time

117. A solid sphere, of radius R acquires a terminal velocity v_1 when falling (due to gravity) through a viscous fluid having a coefficient of viscosity η. The sphere is broken into 27 identical solid spheres. If each of these spheres acquires a terminal velocity, v_2, when falling through the same fluid, the ratio (v_1/v_2) equals :

[12 April, 2019 (Shift-II)]

(a) 27 (b) 1/27

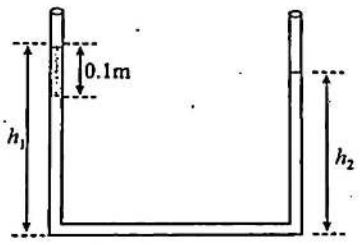
(c) 9 (d) 1/9

JEE-Advanced

Calculation of Pressure, Pascal's Law

Single Correct

1. An open-ended U-tube of uniform cross-sectional area contains water (density 10^3 kg m^{-3}). Initially the water level stands at 0.29 m from the bottom in each arm. Kerosene oil (a water-immiscible liquid) of density 800 kg m^{-3} is added to the left arm until its length is 0.1 m, as shown in the schematic figure below. The ratio $\left(\frac{h_1}{h_2}\right)$ of the heights of the liquid in the two arms is:

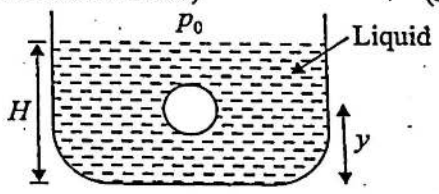


C-32.48 W-27.38 UA-40.14 PC-0 (JEE Adv. 2020)

(a) $\frac{15}{14}$ (b) $\frac{35}{33}$

(c) $\frac{7}{6}$ (d) $\frac{5}{4}$

2. A small spherical monatomic ideal gas bubble ($\gamma = 5/3$) is trapped inside a liquid of density ρ_l (see figure). Assume that the bubble does not exchange any heat with the liquid. The bubble contains n moles of gas. The temperature of the gas when the bubble is at the bottom is T_0, the height of the liquid is H and the atmospheric pressure is p_0 (Neglect surface tension) (JEE Adv. 2008)



When the gas bubble is at a height y from the bottom, its temperature is

@FAKE_CBSE_GUIDEDUNET

(a) $T_0\left(\frac{p_0+\rho_l gH}{p_0+\rho_l gy}\right)^{2/5}$ (b) $T_0\left(\frac{p_0+\rho_l g(H-y)}{p_0+\rho_l gH}\right)^{2/5}$

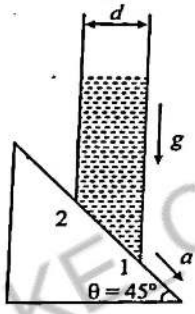
(c) $T_0\left(\frac{p_0+\rho_l gH}{p_0+\rho_l gy}\right)^{3/5}$ (d) $T_0\left(\frac{p_0+\rho_l g(H-y)}{p_0+\rho_l gH}\right)^{3/5}$

3. A closed compartment containing gas is moving with some acceleration in horizontal direction. Neglect effect of gravity. Then, the pressure in the compartment is **(IIT-JEE 1999)**
(a) Same everywhere (b) Lower in the front side
(c) Lower in rear side (d) Lower in upper side

4. A U-tube of uniform cross-section is partially filled with a liquid I. Another liquid II which does not mix with liquid I is poured into one side. It is found that the liquid levels of the two sides of the tube are the same, while the level of liquid I has risen by 2cm. If the specific gravity of liquid I is 1.1, the specific gravity of liquid II must be **(IIT-JEE 1983)**
(a) 1.12 (b) 1.1 (c) 1.05 (d) 1.0

Multiple Correct

5. A cylindrical tube, with its base as shown in the figure, is filled with water. It is moving down with a constant acceleration a along a fixed inclined plane with angle $\theta = 45°$. P_1 and P_2 are pressures at points 1 and 2, respectively, located at the base of the tube. Let $\beta = (P_1 - P_2)/(\rho g d)$, where ρ is density of water, d is the inner diameter of the tube and g is the acceleration due to gravity. Which of the following statement(s) is (are) correct?



C-6.31 W-24.09 UA-61.58 PC-8.02 (JEE Adv. 2021)

(a) $\beta = 0$ when $a = g/\sqrt{2}$ (b) $\beta > 0$ when $a = g/\sqrt{2}$

(c) $\beta = \frac{\sqrt{2}-1}{\sqrt{2}}$ when $a = g/2$ (d) $\beta = \frac{1}{\sqrt{2}}$ when

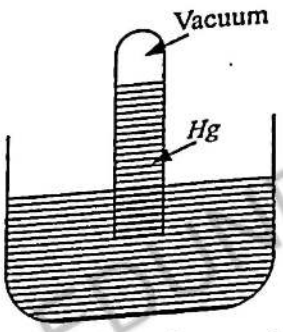
Numerical Types/Integer Types

6. A cylindrical vessel of height 500 mm has an orifice (small hole) at its bottom. The orifice is initially closed and water is filled in it upto height H. Now, the top is completely sealed with a cap and the orifice at the bottom is opened. Some water comes out from the orifice and the water level in the vessel becomes steady with the height of the water column being 200mm. Find the fall in height (in mm) of water level due to opening of the orifice.
[Take atmospheric pressure = 10×10^5 Nm^{-2}, density of water = 1000 kg.m^{-3} and g = 10 ms^{-2}. Neglect any effect of surface tension.] **(JEE Adv. 2009)**

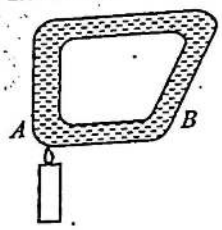
7. A column of mercury of length 10 cm is contained in the middle of a horizontal tube of length 1m which is closed at both the ends. The two equal lengths contain air at standard atmospheric pressure of 0.76 m of mercury. The tube is now turned to a vertical position. By what distance will the column of mercury be displaced? Assume temperature to be constant. **(IIT JEE 1978)**

True/False

8. A barometer made of a very narrow tube (see figure) is placed at normal temperature and pressure. The coefficient of volume expansion of mercury is 0.00018/°C and that of the tube is negligible. The temperature of mercury in the barometer is now raised by 1°C but the temperature of the atmosphere does not change. Then, the mercury height in the tube remains unchanged **(IIT-JEE 1983)**

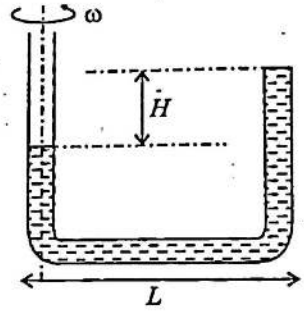


9. Water in a closed tube (see figure) is heated with one arm vertically placed above a lamp. Water will begin to circulate along the tube in counter-clockwise direction. **(IIT-JEE 1983)**



Subjective

10. A U-shaped tube contains a liquid of density ρ and it is rotated about the line as shown in the figure. Find the difference in the levels of the liquid column. **(JEE Adv. 2005)**



11. Two identical cylindrical vessels with their bases at the same level each contain a liquid of density ρ. The height of the liquid in one vessel is h_1 and in the other is h_2. The area of either base is A. What is the work done by gravity in equalizing the levels when the two vessels are connected? **(IIT JEE 1981)**

@FAKE CBSE X @PHYSICS SHEET

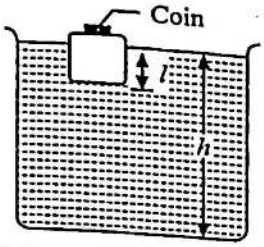
"Archimedes Principle and Force of Buoyancy"

Single Correct

12. A thin uniform cylindrical shell, closed at both ends, is partially filled with water. It is floating vertically in water in a half-submerged state. If ρ_r is the relative density of the material of the shell with respect to water, then the correct statement is that the shell is
C-15.83 W-40.69 UA-43.48 **(JEE Adv. 2012)**

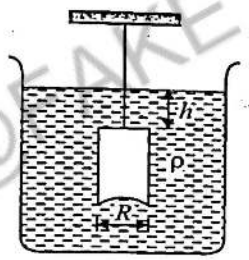
(a) More than half-filled if ρ_r is less than 0.5
(b) More than half-filled if ρ_r is more than 1.0
(c) Half-filled if ρ_r is more than 0.5
(d) Less than half-filled if ρ_r is less than 0.5

13. A wooden block, with a coin placed on its top, floats in water as shown in figure. The distance l and h are shown there. After some time the coin falls into the water. Then **(IIT-JEE 2002)**



(a) l decreases and h increases (b) l increases and h decreases
(c) Both l and h increase (d) Both l and h decrease

14. A hemispherical portion of radius R is removed from the bottom of a cylinder of radius R. The volume of the remaining cylinder is V and mass M. It is suspended by a string in a liquid of density ρ, where it stays vertical. The upper surface of the cylinder is at a depth h below the liquid surface. The force on the bottom of the cylinder by the liquid is **(IIT-JEE 2001)**

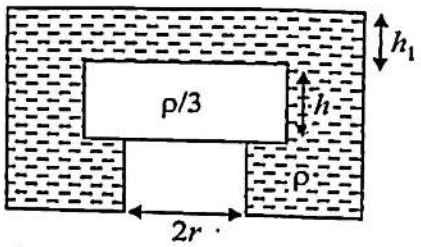


(a) Mg (b) $Mg - V\rho g$
(c) $Mg + \pi R^2 h\rho g$ (d) $\rho g(V + \pi R^2 h)$

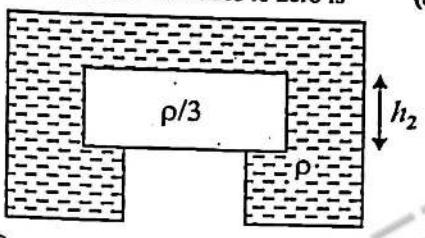
15. A vessel contains oil (density = 0.8 g/cm³) over mercury (density =13.6 g/cm³). A homogeneous sphere floats with half its volume immersed in mercury and the other half in oil. The density of the material of the sphere in g/cm³ is **(IIT JEE 1988)**

(a) 3.3 (b) 6.4
(c) 7.2 (d) 12.8

16. A wooden cylinder of diameter $4r$, height h and density $\rho/3$ is kept on a hole of diameter $2r$ of the tank, filled with liquid of density ρ as shown in the figure.

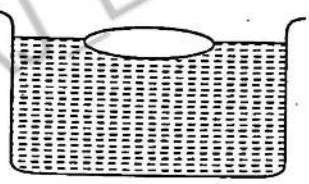


The block in the above question is maintained at the position by external means and the level of liquid is lowered. The height h_2 when this external force reduces to zero is **(JEE Adv. 2006)**



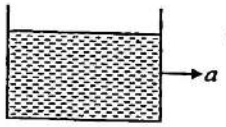
(a) $4h/9$ (b) $5h/9$
(c) Remains same (d) $2h/3$

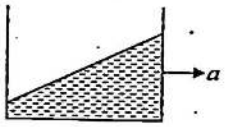
17. A body floats in a liquid contained in a beaker. The whole system as shown in figure falls freely under gravity. The upthrust on the body is **(IIT-JEE 1982)**

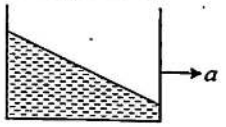


(a) Zero
(b) Equal to the weight of liquid displaced
(c) Equal to the weight of the body in air
(d) Equal to the weight of the immersed portion of the body

18. A vessel containing water is given a constant acceleration towards the right along a straight horizontal path. Which of the following diagrams represents the surface of the liquid? **(IIT-JEE 1981)**

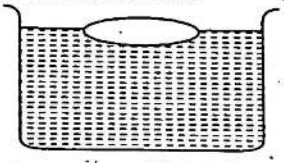
(a) 

(b) 

(c) 

(d) None of these

19. A metal ball immersed in alcohol weighs w_1 at 0°C and w_2 at 50°C. The coefficient of cubical expansion of the metal is less than that of the alcohol. Assuming that the density of the metal is large compared to that of alcohol, it can be shown that **(IIT-JEE 1980)**



(a) $w_1 > w_2$ (b) $w_1 = w_2$
(c) $w_1 < w_2$ (d) All of these

@FAKE_BOOK@RAILEDUNET

20. The buoyancy force acting on the gas bubble is (Assume R is the universal gas constant) **(IIT-JEE 2008)**

(a) $\rho_l nRgT_0 \dfrac{(p_0+\rho_l gH)^{2/5}}{(p_0+\rho_l gy')^{2/5}}$

(b) $\dfrac{\rho_l nRgT_0}{(p_0+\rho_l gH)^{2/5}[p_0+\rho_l g(H-y')]^{1/5}}$

(c) $\rho_l nRgT_0 \dfrac{(p_0+\rho_l gH)^{3/5}}{(p_0+\rho_l gy')^{8/5}}$

(d) $\dfrac{\rho_l nRgT_0}{(p_0+\rho_l gH)^{3/5}[p_0+\rho_l g(H-y')]^{2/5}}$

Multiple Correct

21. A solid sphere of radius R and density ρ is attached to one end of a massless spring of force constant k. The other end of the spring is connected to another solid sphere of radius R and density 3ρ. The complete arrangement is placed in a liquid of density 2ρ and is allowed to reach equilibrium. The correct statement(s) is (are)

C-15.5 W-41.64 UA-42.85 (JEE Adv. 2013)

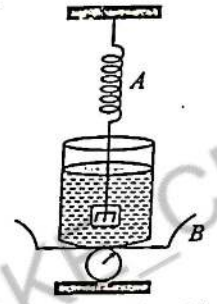
(a) The net elongation of the spring is $(4\pi R^3\rho g)/3k$

(b) The net elongation of the spring is $(8\pi R^3\rho g)/3k$

(c) The light sphere is partially submerged

(d) The light sphere is completely submerged

22. The spring balance A reads 2 kg with a block m suspended from it. A balance B reads 5 kg when a beaker with liquid is put on the pan of the balance. The two balances are now so arranged that the hanging mass is inside the liquid in the beaker as shown in the figure. In this situation. **(IIT-JEE 1985)**



(a) The balance A will read more than 2 kg

(b) The balance B will read more than 5 kg

(c) The balance A will read less than 2 kg and B will read more than 5 kg

(d) The balances A and B will read 2 kg and 5 kg respectively

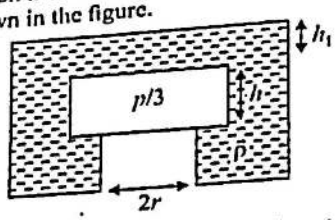
Numerical Types/Integer Types

23. A hot air balloon is carrying some passengers, and a few sandbags of mass 1 kg each so that its total mass is 480 kg. Its effective volume giving the balloon its buoyancy is V. The balloon is floating at an equilibrium height of 100 m. When N number of sandbags are thrown out, the balloon rises to a new equilibrium height close to 150 m with its volume V remaining unchanged. If the variation of the density of air with height h from the ground is $\rho(h)=\rho_0 e^{-\frac{h}{h_0}}$, where ρ_0=1.25 kg m^{-3} and h_0= 6000 m, the value of N is _____.

C-5.02 W-16.05 UA-78.93 (JEE Adv. 2020)

Comprehension Based/Passage Based

Direction (Q. 38-39): A wooden cylinder of diameter 4r, height h and density ρ/3 is kept on a hole of diameter 2r of the tank, filled with liquid of density ρ as shown in the figure. **(JEE Adv. 2006)**



24. Now the level of the liquid starts decreasing slowly. When the level of liquid is at a height h_1 above the cylinder the block starts moving up. At what value of h_1, will the block rise?

(a) $4h/9$ (b) $5h/9$

(c) $5h/3$ (d) Remains same

25. If height h_2 of water level is further decreased, then

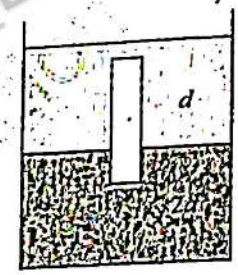
(a) Cylinder will not move up and remains at its original position

(b) For $h_2 = h/3$, cylinder again starts moving up

(c) For $h_2 = h/4$, cylinder again starts moving up

(d) For $h_2 = h/5$, cylinder again starts moving up

26. A homogeneous solid cylinder of length L and cross-sectional area A/5 is immersed such that it floats with its axis vertical at the liquid-liquid interface with length L/4 in the denser liquid as shown in the figure. The lower density liquid is open to atmosphere having pressure P_0 **(IIT-JEE 1995)**



Then, density D of solid is given by

(a) $5/4d$ (b) $4/5d$ (c) $4d$ (d) $d/5$

Fill in the Blanks

27. A piece of metal floats on mercury. The coefficients of volume expansion of the metal and mercury are γ_1 and γ_2 respectively. If the temperatures of both mercury and the metal are increased by an amount ΔT, the fraction of the volume of the metal submerged in mercury changes by the factor _____. **(IIT-JEE 1991)**

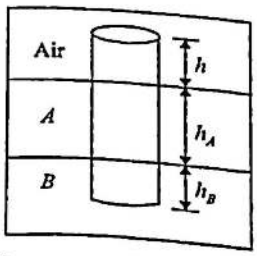
True/False

28. A block of ice with a lead shot embedded in it is floating on water contained in a vessel. The temperature of the system is maintained at 0°C as the ice melts. When the ice melts completely the level of water in the vessel rises. **(IIT-JEE 1986)**

Subjective

29. A uniform solid cylinder of density 0.8 g/cm^3 floats in equilibrium in a combination of two non-mixing liquids A and B with its axis vertical. The densities of the liquids A and B are 0.7 g/cm^3 and 1.2 g/cm^3, respectively. The height of liquid A is h_A = 1.2 cm. The length of the part of the cylinder immersed in liquid B is h_B = 0.8 cm. **(IIT-JEE 2002)**

@RAJ_EDUCATIONAL_INFO @TEAM_CBSE X



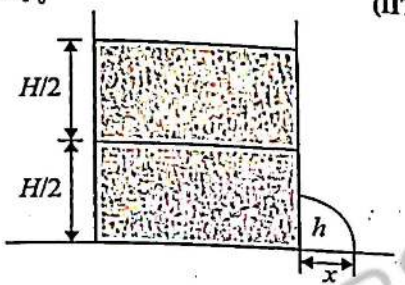
(a) Find the total force exerted by liquid A on the cylinder.

(b) Find h, the length of the part of the cylinder in air.

(c) The cylinder is depressed in such a way that its top surface is just below the upper surface of liquid A and is then released. Find the acceleration of the cylinder immediately after it is released.

30. A wooden stick of length L, radius R and density ρ has a small metal piece of mass m (of negligible volume) attached to its one end. Find the minimum value for the mass m (in terms of given parameters) that would make the stick float vertically in equilibrium in a liquid of density $\sigma(>\rho)$ **(IIT-JEE 1999)**

31. A container of large uniform cross-sectional area A resting on a horizontal surface, holds two immiscible, non-viscous and incompressible liquids of densities d and 2d, each of height H/2 as shown in figure. The lower density liquid is open to the atmosphere having pressure p_0 **(IIT-JEE 1995)**



A homogeneous solid cylinder of length $L(L<H/2)$, cross-sectional area $A/5$ is immersed such that it floats with its axis vertical at the liquid-liquid interface with length $L/4$ in the denser liquid. Determine

(a) the density D of the solid,

(b) the total pressure at the bottom of the container.

32. A ball of density d is dropped onto a horizontal solid surface. It bounces elastically from the surface and returns to its original position in a time t_1. Next, the ball is released and it falls through the same height before striking the surface of a liquid of density d_L **(IIT-JEE 1992)**

(a) If $d<d_L$, obtain an expression (in terms of d, t_1 and d_L) for the time t_2 the ball takes to come back to the position from which it was released.

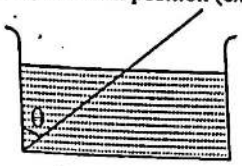
(b) Is the motion of the ball simple harmonic?

(c) If $d=d_L$, how does the speed of the ball depend on its depth inside the liquid?

Neglect all frictional and other dissipative forces. Assume the depth of the liquid to be large.

33. A boat floating in a water tank is carrying a number of large stones. If the stones are unloaded into water, what will happen to the water level? **(IIT-JEE 1979)**

34. A wooden plank of length 1 m and uniform cross-section is hinged at one end to the bottom of a tank as shown in figure. The tank is filled with water upto a height 0.5 m. The specific gravity of the plank is 0.5. Find the angle q that the plank makes with the vertical in the equilibrium position (exclude the case $\theta = 0°$).

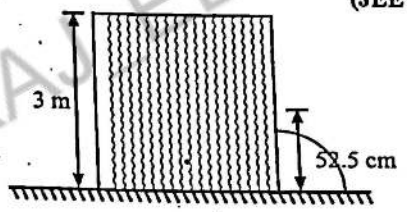


(IIT-JEE 1984)

"Continuity Equation, Bernoulli Theorem and Their Application"

Single Correct

35. Water is filled in a cylindrical container to a height of 3 m. The ratio of the cross-sectional area of the orifice and the beaker is 0.1. The square of the speed of the liquid coming out from the orifice is $(g = 10\ m/s^2)$ **(JEE Adv. 2005)**



(a) $50\ m^2/s^2$ (b) $50.5\ m^2/s^2$ (c) $51\ m^2/s^2$ (d) $52\ m^2/s^2$

36. A large open tank has two holes in the wall. One is a square hole of side L at a depth y from the top and the other is a circular hole of radius R at a depth $4y$ from the top. When the tank is completely filled with water, the quantities of water flowing out per second from both holes are the same. Then, R is equal to **(IIT-JEE 2000)**

(a) $\frac{L}{\sqrt{2\pi}}$ (b) $2\pi L$ (c) L (d) $\frac{L}{2\pi}$

37. Water from a tap emerges vertically downwards with an initial speed of 1.0m/s. The cross-sectional area of the tap is $10^{-4}\ m^2$. Assume that the pressure is constant throughout the steam of water and that the flow is steady, the cross-sectional area of stream 0.15m below the tap is **(IIT-JEE 1998)**

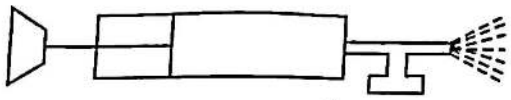
(a) $5.0 \times 10^{-4}\ m^2$ (b) $1.0 \times 10^{-4}\ m^2$

(c) $5.0 \times 10^{-5}\ m^2$ (d) $2.0 \times 10^{-5}\ m^2$

Comprehension Based/Passage Based

A spray gun is shown in the figure where a piston pushes air out of nozzle. A thin tube of uniform cross-section is connected to the nozzle. The other end of the tube is in a small liquid container. As the piston pushes air through the nozzle, the liquid from the container rises into the nozzle and is sprayed out. For the spray gun shown, the radii of the piston and the nozzle are 20 mm and 1 mm respectively. The upper end of the container is open to the atmosphere.

@FAKE_JEE X @RAJ_EDUNET



38. If the piston is pushed at a speed of 5 mm/s, the air comes out of the nozzle with a speed of

C-45.62 W-28.4 UA-25.97 (JEE Adv. 2014)

(a) 0.1 ms^{-1} (b) 1 ms^{-1} (c) 2 ms^{-1} (d) 8 ms^{-1}

39. If the density of air is ρ_a and that of the liquid ρ_l, then for a given piston speed the rate (volume per unit time) at which the liquid is sprayed will be proportional to

C-23.3 W-31.22 UA-45.48 (JEE Adv. 2014)

(a) $\sqrt{\frac{\rho_a}{\rho_l}}$ (b) $\sqrt{\rho_a \rho_l}$ (c) $\sqrt{\frac{\rho_l}{\rho_a}}$ (d) ρ_l

Match the Column

40. A person in a lift is holding a water jar, which has a small hole at the lower end of its side. When the lift is at rest, the water jet coming out of the hole hits the floor of the lift at a distance d of 1.2m from the person. In the following, the state of the lift's motion is given in List-I and the distance where the water jet hits the floor of the lift is given in List-II. Match the statements from List-I with those in List-II and select the correct answer using the code given below the lists. C-16.16 W-73.98 UA-9.85 (JEE Adv. 2014)

List-I		List-II	
A.	Lift is accelerating vertically up.	(p)	$d = 1.2$ m
B.	Lift is accelerating vertically down with an acceleration less than gravitational acceleration.	(q)	$d > 1.2$ m
C.	Lift is moving vertically up with constant speed.	(r)	$d < 1.2$ m
D.	Lift is falling freely.	(s)	No water leaks out of the jar

(a) A-q, B-r, C-q, D-s
(b) A-q, B-r, C-p, D-s
(c) A-p, B-p, C-p, D-s
(d) A-q, B-r, C-p, D-p

Numerical Types/Integer Types

41. A train with cross-sectional area S_t is moving with speed v_t inside a long tunnel of cross-sectional area $S_0 (S_0 = 4S_t)$. Assume that almost all the air (density ρ) in front of the train flows back between its sides and the walls of the tunnel. Also, the air flow with respect to the train is steady and laminar. Take the ambient pressure and that inside the train to be p_0. If the pressure in the region between the sides of the train and the tunnel walls is p, then $p_0 - p = \frac{7}{2N}\rho v_t^2$. The value of N is _____. C-1.47 W-20.13 UA-78.4 (JEE Adv. 2020)

42. A horizontal pipeline carries water in a streamline flow. At a point along the pipe, where the cross-sectional area is 10 cm^2, the water velocity is 1 ms^{-1} and the pressure is 2000 P_a. The pressure of water at another point where the cross-sectional area is 5 cm^2, is ...,. P_a. (Density of water = 10^3 kg-m^3) (IIT-JEE 1994)

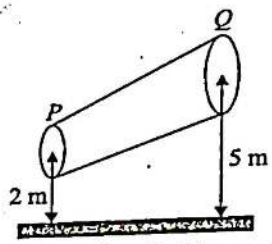
Assertion and Reason/Statement Based

43. **Statement-I:** The stream of water flowing at high speed from a garden hose pipe tends to spread like a fountain when held vertically up, but tends to narrow down when held vertically down.
Statement-II: In any steady flow of an incompressible fluid, the volume flow rate of the fluid remains constant. (2008 IIT-JEE)
Mark your answer as
(a) If Statement-I is true, Statement-II is true; Statement-II is the correct explanation for Statement-I.
(b) If Statement-I is true, Statement-II is true; Statement-II is not a correct explanation for Statement-I.
(c) If Statement-I is true; Statement-II is false.
(d) If Statement-I is false; Statement-II is true.

Subjective

44. Consider a horizontally oriented syringe containing water located at a height of 1.25 m above the ground. The diameter of the plunger is 8mm and the diameter of the nozzle is 2mm. The plunger is pushed with a constant speed of 0.25 m/s. Find the horizontal range of the water stream on the ground. (Take $g = 10$ m/s^2) (IIT-JEE 2004)

45. A non-viscous liquid of constant density 1000 kg/m^3 flows in streamline motion along a tube of variable cross-section. The tube is kept inclined in the vertical plane as shown in the figure. The area of cross-section of the tube at two points P and Q at heights of 2 m and 5 m are respectively 4×10^{-3} m^2 and 8×10^{-3} m^2. The velocity of the liquid at point P is 1 m/s. Find the work done per unit volume by the pressure and the gravity forces as the fluid flows from point P to Q. (IIT-JEE 1997)



46. A large open top container of negligible mass and uniform cross-sectional area A has a small hole of cross-sectional area A/100 in its side wall near the bottom. The container is kept on a smooth horizontal floor and contains a liquid of density ρ and mass m. Assuming that the liquid starts flowing out horizontally through the hole at $t = 0$. Calculate (IIT-JEE 1997)
(a) The acceleration of the container and
(b) Velocity of efflux when 75% of the liquid has drained out

Viscosity and Viscous Force

Multiple Correct

47. Consider a thin square plate floating on a viscous liquid in a large tank. The height h of the liquid in the tank is much less than the width of the tank. The floating plate is pulled horizontally with a constant velocity u_0. Which of the following statements is (are) true?
C-9.64 W-16.36 UA-36.76 PC-37.24 (JEE Adv. 2018)

@FAKE_CODE_X @FAKE_CUNET

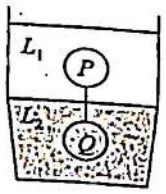
(a) The resistive force of liquid on the plate is inversely proportional to h

(b) The resistive force of liquid on the plate is independent of the area of the plate

(c) The tangential (shear) stress on the floor of the tank increases with u_0

(d) The tangential (shear) stress on the plate varies linearly with the viscosity η of the liquid

48. Two spheres P and Q for equal radii have densities ρ_1 and ρ_2, respectively. The spheres are connected by a massless string and placed in liquids L_1 and L_2 of densities σ_1 and σ_2 and viscosities η_1 and η_2, respectively. They float in equilibrium with the sphere P in L_1 and sphere Q in L_2 and the string being taut (see figure). If sphere P alone in L_2 has terminal velocity v_P and Q alone in L_1 has terminal velocity v_Q, then **(JEE Adv. 2015)**



(a) $|v_P|/|v_Q| = \eta_1/\eta_2$ (b) $|v_P|/|v_Q| = \eta_2/\eta_1$

(c) $v_P \cdot v_Q > 0$ (d) $v_P \cdot v_Q < 0$

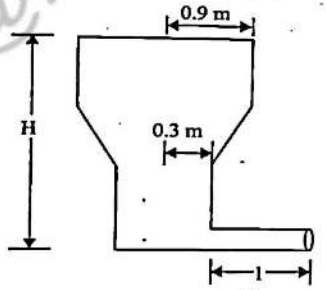
Numerical Types/Integer Types

49. Consider two solid spheres P and Q each of density 8g cm^{-3} and diameters 1 cm and 0.5 cm, respectively. Sphere P is dropped into a liquid of density 0.8 gm/cm^3 and viscosity $\eta = 3$ Poiseuille's. Sphere Q is dropped into a liquid of density 1.6 gm/cm^3 and viscosity $\eta = 2$ Poiseuille's. The ratio of the terminal velocities of P and Q is **C-42.06 W-53.93 UA-4 (JEE Adv. 2016)**

50. A liquid of density 900 kg/m^3 is filled in a cylindrical tank of upper radius 0.9 m and lower radius 0.3 m. A capillary tube of length l is attached at the bottom of the tank as shown in the figure. The capillary has outer radius 0.002 m and inner radius a. When pressure p is applied at the top of the tank, the volume flow rate of the liquid is 8×10^{-6} m^3/s and if the capillary tube is detached, the liquid comes out from the tank with a velocity 10 m/s. **(JEE Adv. 2003)**

Determine the coefficient of viscosity of the liquid.

[Given, $\pi a^2 = 10^{-6}$ m^2 and $a^2/l = 2 \times 10^{-6}$ m]



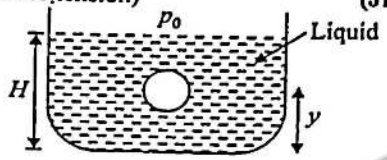
Subjective

51. A small sphere falls from rest in a viscous liquid. Due to friction, heat is produced. Find the relation between the rate of production of heat and the radius of the sphere at terminal velocity. **(JEE Adv. 2004)**

Surface Tension, Surface Energy, Excess Pressure, Capillary Rise, Viscosity and Viscous Force

Single Correct

52. A small spherical monatomic ideal gas bubble ($\gamma = 5/3$) is trapped inside a liquid of density ρ_l (see figure). Assume that the bubble does not exchange any heat with the liquid. The bubble contains n moles of gas. The temperature of the gas when the bubble is at the bottom is T_0, the height of the liquid is H and the atmospheric pressure is p_0 (Neglect surface tension) **(JEE Adv. 2008)**



As the bubble moves upwards, besides the buoyancy force the following forces are acting on it.

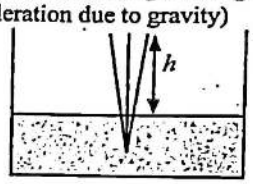
(a) Only the force of gravity

(b) The force due to gravity and the force due to the pressure of the liquid

(c) The force due to gravity, the force due to the pressure of the liquid and the force due to viscosity of the liquid

(d) The force due to gravity and the force due to viscosity of the liquid

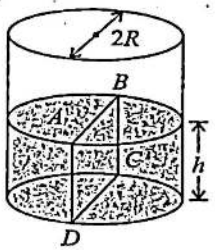
53. A glass capillary tube is of the shape of a truncated cone with an apex angle α so that its two ends have cross-sections of different radii. When dipped in water vertically, water rises in it to a height h, where the radius of its cross-section is b. If the surface tension of water is S, its density is ρ, and its contact angle with glass is θ, the value of h will be (g is the acceleration due to gravity) **(JEE Adv. 2014)**



(a) $2S/b\rho g \cos(\theta - \alpha)$ (b) $2S/b\rho g \cos(\theta + \alpha)$

(c) $2S/b\rho g \cos(\theta - \alpha/2)$ (d) $2S/b\rho g \cos(\theta + \alpha/2)$

54. Water is filled up to a height h in a beaker of radius R as shown in the figure. The density of water is ρ, the surface tension of water is T and the atmospheric pressure is p_0. Consider a vertical section $ABCD$ of the water column through a diameter of the beaker. The force on water on one side of this section by water on the other side of this section has magnitude. **(JEE Adv. 2007)**

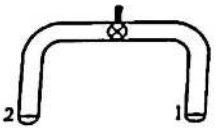


(a) $|2p_0Rh + \pi R^2\rho gh - 2RT|$ (b) $|2p_0Rh + R\rho gh^2 - 2RT|$

(c) $|p_0\pi R_2 + R\rho gh^2 - 2RT|$ (d) $|p_0\pi R_2 + R\rho gh^2 + 2RT|$

@IAS_EXAM_GROUP_EDUNET

55. A glass tube of uniform internal radius (r) has a valve separating the two identical ends. Initially, the valve is in a tightly closed position. End 1 has a hemispherial soap bubble of radius r. End 2 has sub-hemispherical soap bubble as shown in figure. Just after opening the valve. (IIT-JEE 2008)



(a) air from end 1 flows towards end 2. No change in the volume of the soap bubbles

(b) air from end 1 flows towards end 2. Volume of the soap bubble at end 1 decreases

(c) no change occurs

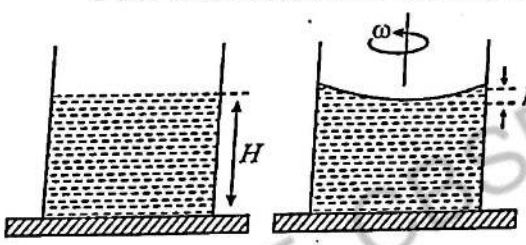
(d) air from end 2 flows towards end 1. Volume of the soap bubble at end 1 increases

Multiple Correct

56. A beaker of radius r is filled with water (refractive index $\frac{4}{3}$) up to a height H as shown in the figure on the left. The beaker is kept on a horizontal table rotating with angular speed ω. This makes the water surface curved so that the difference in the height of water level at the center and at the circumference of the beaker is $h(h << H, h << r)$, as shown in the figure on the right. Take this surface to be approximately spherical with a radius of curvature R. Which of the following is/are correct?

(g is the acceleration due to gravity)

C-7.99 W-23.73 UA-56.53 PC-11.75 (JEE Adv. 2020)



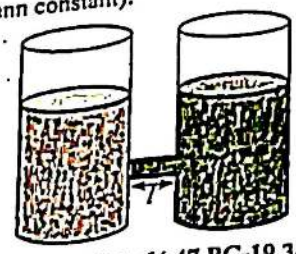
(a) $R=\frac{h^2+r^2}{2h}$

(b) $R=\frac{3r^2}{2h}$

(c) Apparent depth of the bottom of the beaker is close to $\frac{3H}{2}\left(1+\frac{\omega^2 H}{2g}\right)^{-1}$

(d) Apparent depth of the bottom of the beaker is close to $\frac{3H}{4}\left(1+\frac{\omega^2 H}{4g}\right)^{-1}$

57. As shown schematically in the figure, two vessels contain water solutions (at temperature T) of potassium permaganate ($KMnO_4$) of different concentrations n_1 and n_2 ($n_1 > n_2$) molecules per unit volume with $\Delta n = (n_1 - n_2) << n_1$. When they are connected by a tube of small length ℓ and cross-sectional area S, $KMnO_4$ starts to diffuse from the left to the right vessel through the tube. Consider the collection of molecules to behave as dilute ideal gases and the difference in their partial pressure in the two vessels causing the diffusion. The speed v of the molecules is limited by the viscous force $-\beta v$ on each molecule, where β is a constant. Neglecting all terms of the order $(\Delta n)^2$, which of the following is/are correct? (k_B is the Boltzmann constant):



C-4.69 W-11.5 UA-64.47 PC-19.34 (JEE Adv. 2020)

(a) The force causing the molecules to move across the tube is $\Delta n k_B T S$

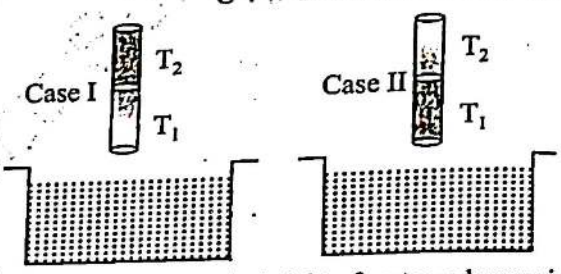
(b) Force balance implies $n_1 \beta v \ell = \Delta n k_B T$

(c) Total number of molecules going across the tube per sec is $\left(\frac{\Delta n}{\ell}\right)\left(\frac{k_B T}{\beta}\right)S$

(d) Rate of molecules getting transferred through the tube does not change with time

58. A cylindrical capillary tube of 0.2 mm radius is made by joining two capillaries T_1 and T_2 of different materials having water contact angles of 0° and 60°, respectively. The capillary tube is dipped vertically in water in two different configurations, case I and II as shown in figure. Which of the following option(s) is(are) correct? (Surface tension of water = 0.075 N/m, density of water = 1000 kg/m³, take $g = 10 m/s^2$)

C-4 W-14 UA-55 PC-27 (JEE Adv, 2019)



(a) The correction in the height of water column raised in the tube, due to weight of water contained in the meniscus, will be different for both cases.

(b) For case I, if the capillary joint is 5 cm above the water surface, the height of water column raised in the tube will be more than 8.75 cm. (Neglect the weight of the water in the meniscus)

(c) For case I, if the joint is kept at 8 cm above the water surface, the height of water column in the tube will be 7.5 cm. (Neglect the weight of the water in the meniscus)

(d) For case II, if the capillary joint is 5 cm above the water surface, the height of water column raised in the tube will be 3.75 cm. (Neglect the weight of the water in the meniscus)

59. A uniform capillary tube of inner radius r is dipped vertically into a beaker filled with water. The water rises to a height h in the capillary tube above the water surface in the beaker. The surface tension of water is σ. The angle of contact between water and the wall of the capillary tube is θ. Ignore the mass of water in the meniscus. Which of the following statements is (are) true? (JEE Adv. 2018)

@FAKE_JEE X @FAKE_JEE_TWEET

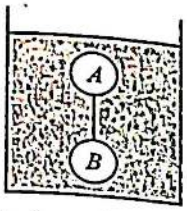
(a) For a given material of the capillary tube, h decreases with increase in r

(b) For a given material of the capillary tube, h is independent of σ

(c) If this experiment is performed in a lift going up with a constant acceleration, then h decreases

(d) h is proportional to contact angle θ

64. Two solid spheres A and B of equal volumes but of different densities d_A and d_B are connected by a string. They are fully immersed in a fluid of density d_F. They get arranged into an equilibrium state as shown in the figure with a tension in the string. The arrangement is possible only if **(IIT-JEE 2011)**



(a) $d_A < d_F$ (b) $d_B > d_F$ (c) $d_A > d_F$ (d) $d_A + d_B = 2d$

Comprehension Based/Passage Based

Direction (Q. 75 to 77): When liquid medicine of density ρ is to be put into the eye, it is done with the help of a dropper. As the bulb on the top of the dropper is pressed, a drop forms at the opening of the dropper. We wish to estimate the size of the drop. We first assume that the drop formed at the opening is spherical because that requires a minimum increase in its surface energy. To determine the size, we calculate the net vertical force due to the surface tension T when the radius of the drop is R. When this force becomes smaller than the weight of the drop, the drop gets detached from the dropper. **(JEE Adv. 2010)**

61. If the radius of the opening of the dropper is r, the vertical force due to the surface tension on the drop of radius R (assuming $r << R$) is

(a) $2\pi rT$ (b) $2\pi RT$ (c) $(2\pi r^2T)/R$ (d) $(2\pi R^2T)/r$

62. If $r = 5 \times 10^{-4}$ m, $\rho = 10^3$ kg.m^{-3}, $g = 10$ ms^{-2}, $T = 0.11$ Nm^{-1}, the radius of the drop when it detaches from the dropper is approximately

(a) 1.4×10^{-3} m (b) 3.3×10^{-3} m

(c) 2.0×10^{-3} m (d) 4.1×10^{-3} m

63. After the drop detaches, its surface energy is

(a) 1.4×10^{-6} J (b) 2.7×10^{-6} J

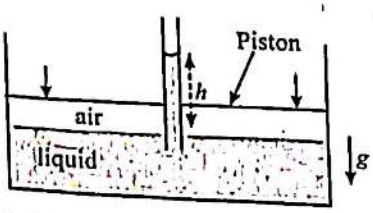
(c) 5.4×10^{-6} J (d) 8.1×10^{-6} J

Numerical Types/Integer Types

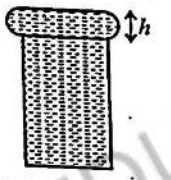
61. An incompressible liquid is kept in a container having a weightless piston with a hole. A capillary tube of inner radius 0.1 mm is dipped vertically into the liquid through the airtight piston hole, as shown in the figure. The air in the container is isothermally compressed from its original volume $\frac{100}{101}V_0$ with the movable piston. Considering ah' as an ideal gas, the height (h) of the liquid column in the capillary above the liquid level in cm is_____.

[Given: Surface tension of the liquid is 0.075 Nm^{-1}, atmospheric pressure is 10^5 Nm^{-2}, acceleration due to gravity (g) is 10 ms^{-2}, density of the liquid is 10^3 kg m^{-3} and contact angle of capillary surface with the liquid is zero]

C-4.03 W-62.65 UA-33.33 (JEE Adv. 2023)



65. When water is filled carefully in a glass, one can fill it to a height h above the rim of the glass due to the surface tension of water. To calculate h just before water starts flowing, model the shape of the water above the rim as a disc of thickness h having semicircular edges, as shown schematically in the figure. When the pressure of water at the bottom of this disc exceeds what can be withstood due to the surface tension, the water surface breaks near the rim and water starts flowing from there. If the density of water, its surface tension and the acceleration due to gravity are 10^3 kg m^{-3}, 0.07 Nm^{-1} and 10 ms^{-2}, respectively, the value of h (in mm) is _____.



C-1.25 W-65.74 UA-33.02 (JEE Adv. 2020)

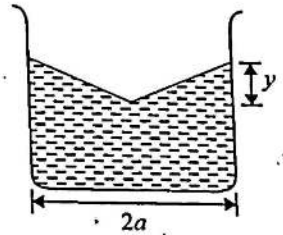
66. A drop of liquid of radius $R = 10^{-2}$ m having surface tension $S = 0.1/4\pi$ Nm^{-1} divides itself into K identical drops. In this process the total change in the surface energy $\Delta U = 10^{-3}$ J. If $K = 10^{\alpha}$, then the value of α is **C-22.62 W-72.36 UA-5.01 (JEE Adv. 2017)**

67. Two soap bubbles A and B are kept in a closed chamber where the air is maintained at pressure 8 Nm^{-2}. The radii of bubbles A and B are 2 cm, respectively. Surface tension of the soap-water used to make bubbles is 0.04 Nm^{-1}. Find the ratio n_B/n_A, where n_A and n_B are the number of moles of air in bubbles A and B, respectively. [Neglect the effect of gravity] **(JEE Adv. 2009)**

Subjective

68. A container of width $2a$ is filled with a liquid. A thin wire of weight per unit length λ is gently placed over the liquid surface in the middle of the surface as shown in the figure.

As a result, the liquid surface is depressed by a distance $y (y << a)$. Determine the surface tension of the liquid. **(JEE Adv. 2004)**



69. A soap bubble is being blown at the end of a very narrow tube of radius b. Air (density ρ) moves with a velocity v inside the tube and comes to rest inside the bubble. The surface tension of the soap solution is T. After sometime the bubble, having grown to radius r separates from the tube. Find the value of r. Assume that $r >> b$ so that you can consider the air to be falling normally on the bubble's surface. **(JEE Adv. 2003)**

@FAKE_CODEX_CRACKEDUNET

ANSWER KEY

JEE-Main

1. [2]	2. [18]	3. [177]	4. (a)	5. (c)	6. (b)	7. (c)	8. [1000 N]	9. (c)	10. (b)
11. (d)	12. (b)	13. [25600]	14. (a, c)	15. [25]	16. (d)	17. (a)	18. [4]	19. [4]	20. (b)
21. (d)	22. (b)	23. (d)	24. (c)	25. (b)	26. [50]	27. [810]	28. [9600]	29. [4]	30. (b)
31. (d)	32. [2]	33. [80]	34. [4]	35. (a)	36. [363]	37. [300]	38. (d)	39. (b)	40. [24]
41. [3]	42. (b)	43. [6]	44. (d)	45. (c)	46. (c)	47. (d)	48. [9]	49. (b)	50. (a)
51. (b)	52. (b)	53. (a)	54. [10]	55. (d)	56. (7)	57. (1)	58. (1)	59. [7]	60. (d)
61. [1]	62. (c)	63. (b)	64. (a)	65. [264]	66. [1150]	67. (a)	68. (a)	69. (c)	70. (a)
71. (a)	72. (a)	73. [3.74]	74. (c)	75. (3)	76. (a)	77. [25]	78. (c)	79. (c)	80. (b)
81. (a,d)	82. (a)	83. (d)	84. (d)	85. (a,c,d)	86. [2]	87. (a)	88. (b)	89. [25]	90. [2]
91. (d)	92. (d)	93. (*)	94. (b)	95. (b)	96. (a)	97. (4)	98. [40]	99. (c)	100. [7]
101. [25]	102. (a)	103. [10]	104. (c)	105. (b)	106. (c)	107. [100]	108. (b)	109. (c)	110. (d)
111. [20]	112. [11]	113. [25]	114. (a)	115. (d)	116. (a,b,c)	117. (c)			

JEE-Advanced

1. (b)	2. (b)	3. (a)	4. (b)	5. (a,c)	6. [6]	7. [2.95]	8. [False]	9. [False]	12. (a)
13. (d)	14. (d)	15. (c)	16. (a)	17. (a)	18. (c)	19. (c)	20. (b)	21. (a,d)	22. (b,c)
23. [4]	24. (c)	25. (a)	26. (a)	28. [False]	35. (a)	36. (a)	37. (c)	38. (c)	39. (a)
40. (c)	41. [9]	42. [500]	43. (a)	44. [2]	47. (a, c, d)	48. (a,d)	49. [3]	50. [1/720]	52. (d)
53. (d)	54. (b)	55. (b)	56. (a,d)	57. (a,b,c)	58. (a,c,d)	59. (a,c)	60. (a,b,d)	61. (c)	62. (a)
63. (b)	64. [25]	65. [3.74]	66. [6]	67. [6]					

EXPLANATIONS

JEE-Main

1. [2] $B = -\frac{\Delta P}{\left(\frac{\Delta V}{V}\right)}$

[–ve sign represent compression]

$\left|\frac{\Delta V}{V}\right| = \frac{h\rho g}{B} = \frac{1000 \times 10 \times 4000}{2 \times 10^9} = 2 \times 10^{-2}$

2. [18] $\beta = \frac{-\Delta P}{\frac{\Delta V}{V}}$

$\Delta P = -\beta \frac{\Delta V}{V}$

$\rho g h = -\beta \frac{\Delta V}{V}$

$10^3 \times 10 \times h = -9 \times 10^8 \times \left(-\frac{0.02}{100}\right)$

$\Rightarrow h = 18m$

3. [177] $F = P_0 A + \rho\, ghA$

Plugging in the given values

$F = 10^5 \times \frac{22}{7} \times (2 \times 10^{-2})^2 + 1.36 \times 10^4 \times 10 \times (30 \times 10^{-2}) \left(\frac{22}{7} \times (2 \times 10^{-2})^2\right)$

$F = 177N$

4. (a) $P = P_0 + \rho gh = 10^5 + 10^3 \times 10 \times 40 = 5 \times 10^5\ Pa$ and temperature is constant

$\Rightarrow PV = P_0 V_0$

$5 \times 10^5 \times 1\text{cm}^3 = 10^5 \times V_0$

$\Rightarrow V_0 = 5\ \text{cm}^3$

5. (c) Weight of the vehicle $F = mg = 5000g$

$= 5000 \times 10 = 5 \times 10^4 N$

Area of cross section = 250 cm²

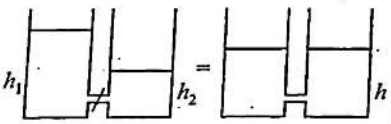
$= 250 \times 10^{-4} m^2$

Maximum pressure

$= \frac{\text{Weight}}{\text{Area of cross section}}$

$= \frac{5 \times 10^4}{250 \times 10^{-4}} = 2 \times 10^6\ Pa$

6. (b)



$h = \frac{h_1 + h_2}{2}$

Now, $W = U_i - U_f$

$W = (\rho A h_1) g \frac{h_1}{2} + (\rho A h_2)$

$g \frac{h_2}{2} - \rho A (h_1 + h_2) g$

$\left(\frac{h_1 + h_2}{4}\right)$

$W = \frac{\rho A g}{2}\left[h_1^2 + h_2^2 - \frac{(h_1 + h_2)^2}{2}\right]$

$W = 1J$

7. (c) We know that,

$P_1 = P_0 + \rho gh \Rightarrow h = \frac{P_1 - P_0}{\rho g}$ and

$P_2 = P_0 + 2\rho gh = P_0 + 2\rho gh$

$\left(\frac{P_1 - P_0}{\rho g}\right) = 2P_1 - P_0$

$\Rightarrow \Delta P = P_2 - P_1 = P_1 - P_0$

$\Rightarrow$ % increment in pressure $= \frac{P_1 - P_0}{P_1} \times 100$

On putting, $P_1 = 3 \times 10^5$ Pa and $P_0 = 10^5$ Pa in above equation, we get

@RAJ_CBSE_RAJ_EDUNET

% increment in pressure

$$=\frac{3\times10^5-1\times10^5}{3\times10^5}\times100=\frac{200}{3}\%$$

8. [1000 N] We know, pressure $=\frac{\text{Force}}{\text{Area}}$

Now, pressure at both the point is same

so, $\frac{F_1}{A_1}=\frac{F_2}{A_2}$

$$\frac{F_1}{\pi(7)^2}=\frac{10}{\pi\times(0.7)^2}$$

$F_1 = 1000$ N

9. (c) Reason is the statement of Pascal's principle and explains the statement given in assertion.

10. (b) At any point on the same horizontal level the pressure in a static liquid will be the same.

$\therefore P=P_{atm}+\rho gh$

Pascal law: Same pressure applied to enclosed water is transmitted in all directions equally.

11. (d) We have, $A = 10$ cm^2, $V = 20$m/s

$F=\rho AV^2=10^3\times10\times10^{-4}\times400=400$N

12. (b) $h_1+h_2=0.29\times2+0.1$

$h_1+h_2=0.68$ ...(a)

$\Rightarrow P_0+\rho_k g(0.1)+\rho_w g(h_1-0.1)$

[ρ_k = density of kerosene and ρ_w = density of water]

$-\rho_w gh_2=P_0$

$\Rightarrow \rho_k g(0.1)+\rho_w gh_1-\rho_w g\times(0.1)=\rho_w gh_2$

$\Rightarrow 800\times10\times0.1+1000\times10\times h_1$

$-1000\times10\times0.1=1000\times10\times h_2$

$\Rightarrow 10000\,(h_1-h_2)=200$

$\Rightarrow h_1-h_2=0.02$ ...(b)

$\Rightarrow h_1=0.35 \Rightarrow h_2=0.33$

So, $\frac{h_1}{h_2}=\frac{35}{33}$

13. [25600] Ratio of masses on two pistons of the hydraulic lift equals to that of their cross – section area.

$\frac{A_1}{A_2}=\frac{100}{m}$

If the diameter of the larger piston is increased by 4 times and that of the smaller piston is decreased by 4 times, then their area (πr^2) is increased and decreased by 16 times respectively.

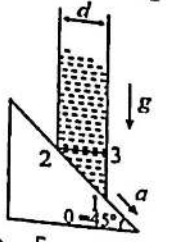
Now, $\frac{16A_1}{A_2/16}=\frac{M}{m}\Rightarrow M=256\frac{A_1}{A_2}\cdot m$

$=25600$ kg

14. (a, c) $\therefore P_1-P_3=\rho\left(g-\frac{a}{\sqrt{2}}\right)d$

$P_2-P_3=\rho\frac{a}{\sqrt{2}}d$

$\therefore P_1-P_2=\rho d\left[g-\frac{2a}{\sqrt{2}}\right]$



$\therefore \frac{P_1-P_2}{\rho gd}=\left[1-\sqrt{2}\frac{a}{g}\right]=\beta$

$\therefore$ if $\beta=0$, $a=\frac{g}{\sqrt{2}}$ ...(A)

$\beta=\frac{\sqrt{2}-1}{2}$, $a=\frac{g}{2}$ ...(C)

15. [25] $y=\frac{\text{stress}}{\text{strain}}=2.0\times10^{10}$

Energy density $=\frac{1}{2}$ stress $\times$ strain

$=\frac{1}{2}(\text{strain})^2 y=\frac{1}{2}(5\times10^{-4})^2\times20\times10^{10}$

$=25\times10^2\times10=25\frac{\text{kJ}}{\text{m}^3}$

16. (d) $v_1\rho_{water}g+v_2\rho_{oil}g=(v_1+v_2)\rho_{ice}g$

$v_1+\frac{v_2\rho_{oil}}{\rho_w}=(v_1+v_2)\frac{\rho_{ice}}{\rho_w}$

$=v_1+0.8\,v_2=0.9\,v_1+0.9\,v_2$

$=0.1\,v_1=0.1\,v_2$

The required ratio of volume, $v_1 : v_2 = 1 : 1$

17. (a) weight $(w)=\frac{4}{3}\pi\left(\frac{D^3-d^3}{8}\right)\sigma g$

Buoyant force

$(F_b)=1\times\frac{4}{3}\pi\left(\frac{D^3}{8}\right)\cdot g$

From the principle of floatation, we have $W=F_b$

$\Rightarrow (D^3-d^3)\sigma=D^3$

$\Rightarrow 1-\frac{d^3}{D^3}=\frac{1}{\sigma}\Rightarrow 1-\frac{1}{\sigma}=\left(\frac{d}{D}\right)^3$

$\Rightarrow\left(\frac{\sigma}{\sigma-1}\right)^{\frac{1}{3}}=\left(\frac{D}{d}\right)$

18. [4] Given, $\omega=x\sqrt{F}$ rad/s

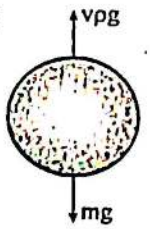
We know that, $F=m\omega^2\frac{L}{2}$

$\Rightarrow F=\frac{mL}{2}\left(x^2F\right)\Rightarrow x^2$

$=\frac{2}{mL}=\frac{2}{\frac{1}{4}\times\frac{1}{2}}=16$

$\therefore x=4$

19. [4]



$480\times g=v\rho_1 g$

$(480-N)g=v\rho_2 g$

$\frac{480-N}{480}=\frac{\rho_2}{\rho_1}$

$\left(1-\frac{N}{480}\right)=\frac{e^{-h_2/h_0}}{e^{-h_1/h_0}}=e^{\frac{h_1-h_2}{h_0}}=e^{\frac{50}{6000}}$

$1-\frac{N}{480}=1-\frac{50}{6000}\Rightarrow N$

$=\frac{50\times480}{6000}=4$

20. (b)

$dVg=\rho\left(\frac{V}{2}\right)g+T(2\pi r)$

$\Rightarrow d.\frac{4}{3}\pi r^3 g=\rho.\frac{2}{3}\pi r^3 g+2\pi rT$

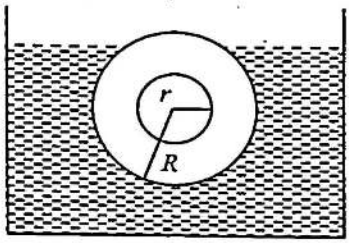
$\Rightarrow \frac{2}{3}r^2g(2d-\rho)=2T$

$\Rightarrow r=\sqrt{\frac{3T}{(2d-\rho)g}}$

21. (d)

Volume of immersed liquid, $V_i=\frac{4}{3}\pi R^3$

Volume of the shell $V_s=\frac{4}{3}\pi\left(R^3-r^3\right)$



In equilibrium

$\frac{4}{2}\pi R^3\rho_w g=\frac{4}{3}\pi\left(R^3-r^3\right)\rho_s\xi$

$\Rightarrow R^3=\left(R^3-r^3\right)\frac{27}{8}$

$\Rightarrow\frac{r^3}{R^3}=\frac{19}{27}\Rightarrow r=\left(\frac{19}{27}\right)^{\frac{1}{3}}\approx\frac{8}{9}R$

22. (b) $\rho=\rho_0\left(1-\frac{r^2}{R^2}\right), 0<r\le R$

As, sphere is floating, so weight of liquid is balanced by buoyancy force.

@FAKE_CBSE_RAJ_EDUNET

$\Rightarrow mg = B$

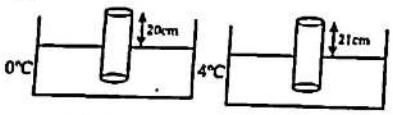
$\Rightarrow \int \rho(4\pi r^2 dr)g = \rho_L \frac{4}{3}\pi R^3 g$

$\int_0^R \rho_0 4\pi\left(r^2 - \frac{r^4}{R^2}\right)dr$

$\Rightarrow = \rho_0 4\pi\left(\frac{r^3}{3} - \frac{r^5}{5R^2}\right)_0^R$

$\Rightarrow \rho_L = \frac{2}{5}\rho_o$

23. *(d)*



$mg = A(80)\,\rho_{0°C}\,g$; $mg = A(79)\,\rho_{4°C}\,g$

$\frac{\rho_{4°C}}{\rho_{0°C}} = \frac{80}{79} = 1.01$

24. *(c)* In Ist situation

$V_b\rho_b g = V_s\rho_w g$

$\frac{V_s}{V_b} = \frac{\rho_b}{\rho_w} = \frac{4}{5}$ ...*(i)*

Here V_b is volume of block

V_s is submerged volume of block

ρ_b is density of block

ρ_w is density of water

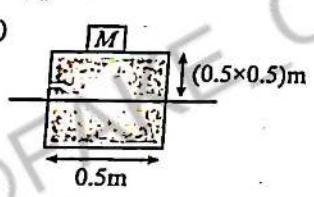
& Let ρ_o is density of oil finally in equilibrium condition

$V_b\rho_b g = \frac{V_b}{2}\rho_0 g + \frac{V_b}{2}\rho_w g$

$2\rho_b = \rho_0 + \rho_w$

$\Rightarrow \frac{\rho_0}{\rho_w} = \frac{3}{5} = 0.6$

25. *(b)*



$M = \rho_L \times$ Volume

$= 10^3[0.5 \times 0.5 \times 0.35]$

$M = 87.5$ kg

26. [50] Change in pressure $= \frac{1}{2}\rho v^2$

$4.5 \times 10^4 - 2.0 \times 10^4 = \frac{1}{2} \times 10^3 \times v^2$

$2.5 \times 10^4 = \frac{1}{2} \times 10^3 \times v^2 \Rightarrow v^2 = 50$

Therefore, Velocity of water $= \sqrt{V} = \sqrt{50}$

$= V = 50$

27. [810] The flow speeds on the upper surfaces of the wings, $v_1 = 70$ ms^{-1}

$v_2 = 65$ ms^{-1}

$A = 2$ m^2

The life of the wing is

$F = \frac{1}{2}\rho(v_1^2 - v_2^2)A$

$F = \frac{1}{2} \times 1.2(70^2 - 65^2) \times 2 = 810$ N

28. [9600] Using Bernoulli equation

$A(P_2 - P_1) = \frac{1}{2}(V_1^2 - V_2^2)A$

[Here, $A = 80$ m^2]

$\Rightarrow mg = \frac{1}{2} \times 1(70^2 - 50^2) \times 80$

$\Rightarrow mg = 40 \times 2400 \Rightarrow m = 9600$ kg

29. [4]

Applying Bernoulli's equation

$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$

For statement-1

Given $V_1 = V_2 = 0$

$\therefore P_1 - P_2 = gg(h_2 - h_1)$

For statement-2

$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

$\Rightarrow P_1 - P_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2$

$\Rightarrow \rho g h = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2$

$\Rightarrow 2gh = v_2^2 - v_1^2$

30. *(b)*

$P + \rho gh + \frac{1}{2}\rho V^2 = \text{constant}$

31. *(d)* $(P_2 - P_1)A = mg$

$\Rightarrow P_2 - P_1 = \frac{5.4 \times 10^6}{500}$

$\Rightarrow P_2 - P_1 = 10.8 \times 10^3\ N/m^2$

Using Bernoulli's theorem,

$P_2 + 0 + \frac{1}{2}\rho v_2^2 = P_1 + 0 + \frac{1}{2}\rho v_1^2$

$P_2 - P_1 = \frac{1}{2}\rho(v_1 - v_2)(v_1 + v_2)$

$10.8 \times 10^3 = \frac{1}{2} \times 1.2(v_1 - v_2) \times 2 \times 3 \times 10^2$

$\Rightarrow v_1 - v_2 = 30$

$\therefore \left(\frac{v_1 - v_2}{v}\right) \times 100 = \frac{30}{300} \times 100 = 10\%$

32. [2] Using equation of continuity

$A_1V_1 = A_2V_2$

$750 \times 10^{-4} V_1 = 500 \times 10^{-6} \times 0.3$

$\Rightarrow V_1 = 2 \times 10^{-3}\ m/s$

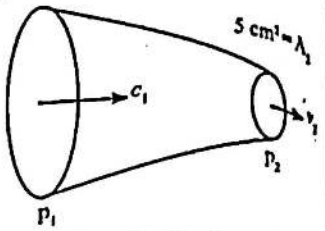
$\Rightarrow \frac{dh}{dt} = 2 \times 10^{-3}\ m/s$

33. [80] Using equation of continuity

$A_1V_1 = A_2V_2$

$V_2 = \frac{A_1V_1}{A_2} = \frac{2 \times 4}{10 \times 10^{-2}} = 80\ cm/s$

34. [4] $A_1 = 10$ cm^2



Pressure drop $\Delta P = P_1 - P_2 = 3$ N/m^2

From continuity equation.

$A_1v_1 = A_2v_2$

$\therefore v_1 = \frac{A_2}{A_1}v_2$

$v_1 = \frac{5}{10}v_2 = \frac{v_2}{2}$

By Bernoulli's eq^n

$P_1 + \frac{1}{2}\rho v_1^{\,2} = P_2 + \frac{1}{2}\rho v_2^{\,2}$

$P_1 - P_2 = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right)$

$\Delta P = \frac{1}{2}\rho\left(v_2^2 - \frac{A_2^2}{A_1^2}v_2^2\right)$

$\Delta p = \frac{1}{2}\rho\left[v_1^2 - \left(\frac{v_2}{2}\right)^2\right]$

$3 = \frac{1}{2} \times 1.25 \times 10^3\left[1 - \frac{1}{4}\right]v_2^2$

$3 = \frac{1}{2} \times 1.25 \times 10^3 \times \frac{3}{4}v_2^2$

$\therefore v_2 = 8 \times 10^{-2}$ m/s

So discharge rate $= A_2v_2$

$= 5 \times 10^{-4} \times 8 \times 10^{-2}$

$= 4 \times 10^{-5}$ m^3/s

35. *(a)* From continuity equation $A_AV_A = A_BV_B$

$1.5 \times V_A = 25 \times 10^{-2} \times 60$

$V_A = \frac{25 \times 60 \times 10^{-2} \times 10}{1.5}$

$V_A = 10$ cm/s

By Bernoulli's theorem

$P_A + \frac{1}{2} \times 1000 \times (0.1)^2$

$= P_B + \frac{1}{2} \times 1000 \times (0.6)^2$

$P_A + 5 = P_B + \frac{1}{2} \times 1000 \times 36 \times 10^{-2}$

$P_A + 5 = P_B + 180$

$P_A - P_B = 175$ Pa

@RAJ_CBSE_K @RAJ_EDUNET

36. [363]

From continuity equation $av_1 = \frac{a}{2}v_2$

$v_2 = 2v_1$

From Bernoulli's theorem,

$$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$$

$$4100 = 800\left[\left(\frac{4v_1^2 - v_1^2}{2}\right) + 10\times(0-1)\right]$$

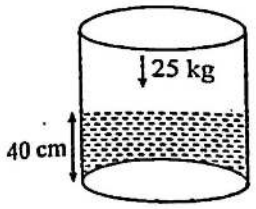
$$\frac{41}{8} + 10 = \frac{3v_1^2}{2}$$

$$v_1 = \sqrt{\frac{121}{4\times 3}\times\frac{3}{3}}$$

$$v_1 = \frac{\sqrt{363}}{6}\text{ m/s}$$

$X = 363$

37. [300]



$$P_0 + \frac{250}{0.5} + \rho g\left(40\times 10^{-2}\right) = P_0 + \frac{1}{2}\rho v^2$$

$$500 + \frac{1000\times 10\times 40}{100} = \frac{1}{2}\times 1000\times v^2$$

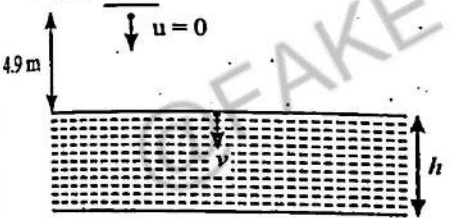
$v = 3$ m/s

$v = 300$ cm/s.

38. (*d*) Given,

Total time, $T = 4$ sec

$u = 0$ m/sec, $g = 9.8$ m/sec^2, $h = 4.9$ m, t=?



Let time taken by ball to hit the surface of water be t, Therefore, from kinematic equation,

$$\Rightarrow h = ut + \frac{1}{2}gt^2$$

$$4.9 = 0t + \frac{1}{2}\times 9.8t^2$$

$t = 1$ s

Now, let assume 'v' be the velocity with which ball hits the water, therefore

$v = u + at$

$= 0 + 9.8 \times 1 = 9.8$ m/sec

Time taken to reach the bottom of the lake from surface of the lake

$= 4 - 1 = 3$ sec

$v = 9.8$ m/sec

Again, from kinematic equation

$$H = 9.8\times 3 + \frac{1}{2}\times 9.8\times(3)^2$$

$H = 73.5$ m

39. (*b*) If is given that, water flow rate, $m = 9 \times 10^4$ kg/hr

$$= \frac{9\times 10^4 \text{ kg/sec}}{60\times 60}$$

$$\therefore \text{mgh} = \frac{9\times 10^4}{60\times 60}\times 10\times 40$$

According to the question, mgh = 10^4 watt

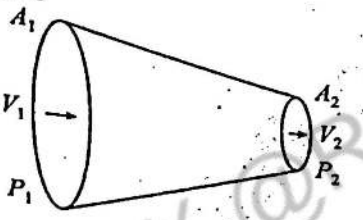
It is given, 50% of it converts into electrical energy = 50% of mgh = $10^4/2$ watt

If n be the number of bulbs then,

$$n\times 100 = \frac{10^4}{2}$$

$\therefore n = 50$

40. [24]



$$A_2 = \frac{A_1}{2}$$

$$P_1 - P_2 = 4500\,Pa$$

$$P_1 + \frac{1}{2}\rho V_1^2 + \rho g h = P_2 + \frac{1}{2}\rho V_2^2 + \rho g h$$

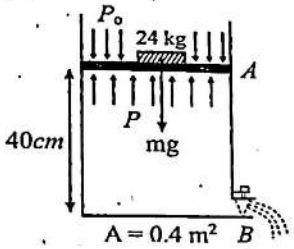
$$P_1 - P_2 = \frac{1}{2}\rho\left(V_2^2 - V_1^2\right)$$

$$A_1 V_1 = A_2 V_2$$

$$4500 = \frac{1}{2}\times 750\times 3V_1^2$$

$$V_1 = 2\text{ m/s} = A_1 V_1 = 24\times 10^{-3}\text{ m}^3\text{ s}^{-1}$$

41. [3]



Force at point A,

$$mg + p_0 A = pA \Rightarrow p = p_0 + \frac{mg}{A}$$

Given, area of

$A = 0.4\text{ m}^2 = 0.4\times 10^4\text{ cm}^2$ and area of

$B = 1$ cm^2

Applying continuity equation

$Av_1 = av$ [V_1 = Velocity at point A]

$$\Rightarrow v_1 = \frac{a}{A}v$$

As $A \gg a$ so $\frac{a}{A}$ very small

$\therefore v_1 << av$

So we can neglect v_1 by assuming $v_1 = 0$

On applying Bernoulli's theorem at points A and B,

$$p_0 + \frac{mg}{A} + \frac{\rho v_1^2}{2} + \rho g h = p_0 + \frac{\rho v^2}{2} + 0$$

$$\Rightarrow p_0 + \frac{mg}{A} + 0 + \rho g h = p_0 + \frac{\rho v^2}{2}$$

$$\Rightarrow \frac{mg}{A} + \rho g h = \frac{\rho v^2}{2}$$

$$\frac{24\times 10}{0.4} + 1000\times 10\times 0.4$$

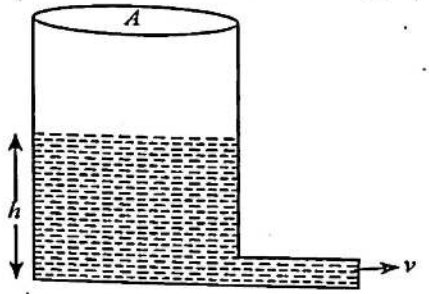
$$\Rightarrow = \frac{1000\times v^2}{2} \Rightarrow v \simeq 3\text{ m/s}$$

42. (*b*) Velocity of efflux, $v = \sqrt{2gh}$

Thrust on the hole

$$F = v\frac{dm}{dt} = v(a\rho v) = v^2 a\rho = 2ghaρ$$

[$\because dm$ = Area × height × density]



Normal reaction on the hole, $R = mg = AH\rho g$

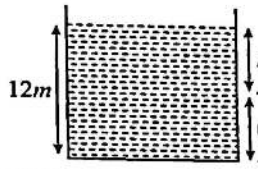
Therefore, friction force $f_r = \mu R = \mu Ah\rho g$

For just sliding, $f_r = F$

$\mu Ah\rho g = 2a\rho gh$

or $\mu = \frac{2a}{A}$

43. [6]



The velocity is given as

$v = \sqrt{2gh}$

Let the hole was made at height below the water level

PEAKE_CBSE_X@RAJ_EDUNET

Then, $H-h=\frac{1}{2}gt^2$

By using the equation

$v=\frac{d}{t} \Rightarrow R=v\times t$

By substituting the time from the above equation we get

$R=\sqrt{2gh}\times\sqrt{\frac{(12-h)\times 2}{g}}$

$\sqrt{4h(12-h)}=R$

For maximum R

$\frac{dR}{dh}=0 \quad \Rightarrow h=6m$

44. *(d)*

Using equation of continuity

$A_1V_1=A_2V_2$

$\frac{V_1}{V_2}=\frac{A_2}{A_1}=\left(\frac{d_2}{d_1}\right)^2=\left(\frac{4.8}{6.4}\right)^2=\frac{9}{16}$

45. *(c)* Using equation of continuity,

$A_1V_1=A_2V_2$

$40\,V_A=20\,V_B \Rightarrow 2V_A=V_B$

Using Bernoullies equation,

$P_A+\frac{1}{2}\rho V_A^2=P_B+\frac{1}{2}\rho V_B^2$

$\Rightarrow P_A-P_B=\frac{1}{2}\rho\left(V_B^2-V_A^2\right)$

$\Rightarrow \Delta P=\frac{1}{2}\times 1000\left(V_B^2-\frac{V_B^2}{4}\right)$

$\Rightarrow \Delta P=500\times\frac{3V_B^2}{4}$

$\Rightarrow V_B=\sqrt{\frac{(\Delta P)\times 4}{1500}}=\sqrt{\frac{(700)\times 4}{1500}}\,m/s$

$=1.37\times 10^2$ cm/s

Volume flow rate $=20\times 1.37\times 10^2=2740$

≈ 2720 cm^3/s

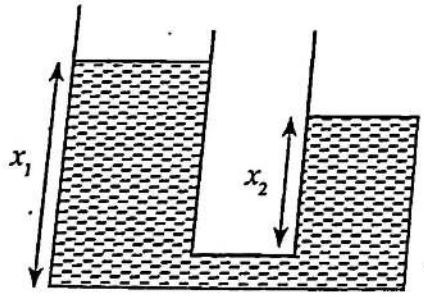
46. *(c)*

Energy in the initial stage

$U_i=Sx_1dg\frac{x_1}{2}+Sx_2dg\frac{x_2}{2}$

Energy in the final stage

$U_f=\frac{S(x_1+x_2)gd}{2}\left(\frac{x_1+x_2}{4}\right)x_2$



$=\frac{s(x_1+x_2)^2gd}{4}$

Change in energy during the process,

$U_i-U_f=\frac{gdS}{4}\left\{2x_1^2+2x_2^2-(x_1+x_2)^2\right\}$

$=\frac{gdS}{4}(x_1-x_2)^2$

47. *(d)*

Using Bernoulli's equation

$P_1+\frac{1}{2}\rho v_1^2+\rho gh_1=P_2+\frac{1}{2}\rho v_2^2+\rho gh_2$

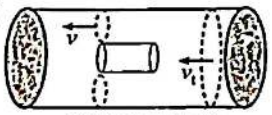
For horizontal tube $h_1=h_2$

$P+\frac{1}{2}\rho v^2=\frac{P}{2}+\frac{1}{2}\rho v^2$

$\frac{1}{2}\rho V^2=\frac{P}{2}+\frac{1}{2}\rho v^2$

$V=\sqrt{\frac{P}{\rho}+v^2}$

48. [9]



with respect to train

Applying Bernoulli's equation

$P_0+\frac{1}{2}\rho v_t^2=P+\frac{1}{2}\rho v^2$

$P_0-P=\frac{1}{2}\rho\left(v^2-v_t^2\right)$ ...(*i*)

From equation of continuity

Also, $4S_iv_t=v\times 3S_i$

$\Rightarrow v=\frac{4}{3}v_t$ ...(*ii*)

From (*i*) and (*ii*)

$P_0-P=\frac{1}{2}\rho\left(\frac{16}{9}v_t^2-v_t^2\right)=\frac{1}{2}\rho\frac{7v_t^2}{9}$

$\therefore N=9$

49. *(b)*

50. *(a)* $\frac{dV}{dt}=\phi-a\sqrt{2hg}=0$

(for maximum height)

$h=\frac{\phi^2}{2ga^2}=\frac{10^{-8}}{2\times 9.8\times 10^{-8}}=5.1$ cm

51. *(b)* $A_1v_1=A_2v_2$

$10^{-4}\times 1=A_2v_2$

$A_2v_2=10^{-4}$ ...(*i*)

$P+\frac{1}{2}\rho(v_1^2-v_2^2)+\rho gh=P$

$v_2^2=v_1^2+2gh$

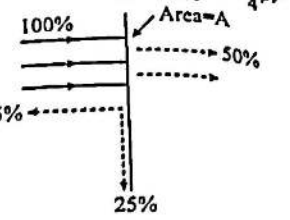
$v_2=\sqrt{v_1^2+2gh}=\sqrt{1+2\times 10\times 0.15}=2$ ...(*ii*)

Using (*i*) and (*ii*), we get

$A_2=5\times 10^{-5}$ m^2

52. *(b)* $F=\frac{1}{4}\times\rho Av^2+\frac{1}{4}2\rho Av^2=\frac{3}{4}\rho Av^2$

Net Pressure $=\frac{F}{A}=\frac{\frac{3}{4}\rho Av^2}{A}=\frac{3}{4}\rho v^2$



53. *(a)* Valume constant

$\frac{4}{3}\pi R^3=27\times\frac{4}{3}\times\pi r^3$

$R^3=27r^3$

$R=3r$

$r=\frac{R}{3}$

$r^2=\frac{R^2}{9}$

Work done $=T.\Delta A=27\,T(4\pi r^2)-T\,4\pi R^2$

$27\,T4\pi\frac{R^2}{9}-4\pi R^2T$

$8\pi R^2T$

54. [10] $\rho(\frac{4}{3}\pi r^3)1000=\frac{4}{3}\pi R^3\rho$

$R=10r$

$E_1=1000\times 4\pi r^2\times S$

$E_2=4\pi(10r)^2\,S$

$\frac{E_1}{E_2}=\frac{10}{1}$, $x=10$

55. *(d)* Lets assume radius of small droplets is r and that of big drop is R.

$\Rightarrow \frac{4}{3}\pi R^5=1000\frac{4}{3}\pi r^5$

$\Rightarrow R=10r$

$U_i=1000\,(4\pi r^2S)$

$U_f=4\pi R^2S=100\,(4\pi r^2S)$

$\therefore \boxed{U_f=\frac{1}{10}U_i}$

56. [7] work $=\Delta U=S\Delta A$

$\Rightarrow 36960 erg$

$=\frac{40 dyne}{cm}8\pi\left[\left(r^2\right)-\left(\frac{7}{2}\right)^2\right]$cm

$\Rightarrow r=7$ cm

57. [1]

1000 × Volume of small droplets = Volume of big drop

$1000\frac{4}{3}\pi r^3=\frac{4}{3}\pi R^3$

$10r=R$

$R=10r$

@FAKE_CBSE_X @RAJEDUNET

$$\frac{\text{Energy of 1000 drops}}{\text{Energy of Big drop}}=\frac{1000(4\pi r^2)T}{4\pi R^2T}$$

$$=\frac{1000\times r^2}{(10r)^2}=10=\frac{10}{x}$$

$$\therefore x=1$$

58. [1] Since, There are two liquid-air surfaces in bubble, therefore

$$\Delta P=2\left(\frac{2S}{R}\right)=\frac{4S}{R}$$

59. [7] the liquid column balances excess pressure of soap bubble so,

$$\rho g h=\frac{4S}{R}$$

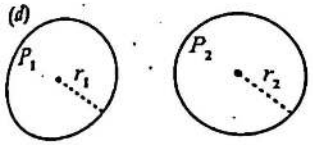
$$\Rightarrow R=\frac{4\times0.28}{8\times10^3\times10\times4\times10^{-4}}$$

$$\Rightarrow\frac{0.28}{8}\text{m}=\frac{28}{8}\text{cm}$$

$$\Rightarrow R=3.5\text{ cm}$$

Diameter $=R\times2=7$ cm

60. (d)



$$P_1-P_0=\frac{4T}{r_1}$$

$$P_2-P_0=\frac{4T}{r_2}$$

According to the question the excess pressure inside a soap bubble is thrice the excess pressure inside a second soap bubble.

$$P_1-P_0=3(P_2-P_0)$$

$$\frac{4T}{r_1}=3\frac{4T}{r_2}$$

$$r_2=3r_1$$

The ratio between the volume of the first and second bubble,

$$\frac{V_1}{V_2}=\frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3}=\frac{1}{27}$$

61. [1]

Surface Tension $=T$

Let, radius of bigger drop $=R$

Let, radius of smaller drop $=r$

As the volume will remain same

$$\Rightarrow\frac{4}{3}\pi R^3=1000\times\frac{4}{3}\pi r^3$$

$$\Rightarrow R=10r$$

Initial surface energy

$$\mu_i=T.4\pi R^2$$

Final surface energy,

$$\mu_f=T.4\pi r^2\times1000$$

$$\therefore\Rightarrow\frac{u_f}{u_i}=\frac{1000r^2}{R^2}$$

$$\Rightarrow\frac{u_f}{u_i}=\frac{10}{1}\qquad[\because R=10r]$$

So, $x=1$

62. (c)

Surface area of a soap bubble $=2\times4\pi R^2$

Work done = change in surface area × *surface tension*

$$=8\pi\times\left(R_2^2-R_1^2\right)\times T_S$$

$$=2\times10^{-2}\times8\times\frac{22}{7}\times49\times\frac{3}{4}\times10^{-4}$$

$$=18.48\times10^{-4}\,J$$

63. (b) Equating the volumes of the smaller drops and bigger drop

$$1000\times\frac{4\pi}{3}(1)^3=\frac{4\pi}{3}R^3$$

$R=10$ mm

$$\because\Delta E=T\times1000\times4\pi(10^{-3})^2-T\times4\pi(10\times10^{-3})^2$$

$$\Rightarrow\Delta E=7.92\times10^{-4}\text{ J}$$

64. (a) Initial surface energy = surface tension × increase in area $=0.45\times4\pi\,(10^{-3})^2$

Equating the volumes of the drops

$$\frac{4}{3}\pi\left(10^{-3}\right)^3=125\times\frac{4\pi}{3}R_{new}^3$$

$$\therefore 10^{-3}=5R_{new}$$

$$\Rightarrow R_{new}=\frac{10^{-3}}{5}\text{m}$$

So, final surface energy

$$=0.45\times125\times4\pi\left(\frac{10^{-3}}{5}\right)^2$$

Increase in energy = final energy − initial energy

$$=0.45\times4\pi\times\left(10^{-3}\right)^2\left[\frac{125}{25}-1\right]$$

$$=2.26\times10^{-5}\text{ J}$$

65. [264] $W=T.(\Delta A)$

$$W=T\left(8\pi\left(r_2^2-r_1^2\right)\right)$$

$$3.5\times10^{-2}\times8\times3.14\times(400\times10^{-4}-100\times10^{-4})$$

$$W=264\times10^{-4}J$$

66. [1150] Given, radius of air bubble, $r=1.0$ mm $=10^{-3}$ m surface tension $T=0.075$ N/M, density of Liquid $r=1000$ kg^{-3} M, depth $h=10$ cm

Pressure inside the bubble

$$P=P_0+h\rho g+\frac{2T}{r}$$

$$P-P_0=0.1\times1000\times10+\frac{2\times.075}{10^{-3}}$$

$$=1000+(0.15)\,(1000)$$

$$=1150\text{ Pa}$$

67. (a) Radius of drop, $r=\frac{2}{2}\text{cm}\div1\times10^{-2}\text{ m}$

Let the radius of droplet be r_o

Volume of drop = 64 × volume of droplet

$$\frac{4}{3}\pi r^3=64\times\frac{4}{3}\pi r_o^3$$

$$r=4r_o$$

$$r_o=\frac{1}{4}r$$

Initial surface area, $A_1=4\pi r^2$

Final surface area, $A_2=64\times4\pi r_o^2$

Change in the area, $\Delta A=A_2-A_1$

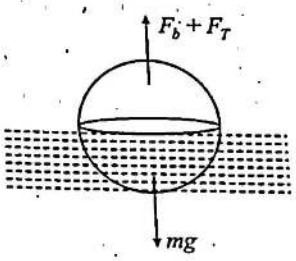
$$=4\pi\left(64\left(\frac{r}{4}\right)^2-r^2\right)=3\times4\pi r^2=12\pi r^2$$

Gain in surface energy, $\Delta U=T\Delta A$

$$\therefore\Delta U=12\pi r^2\cdot T=12\times3.14\times10^{-4}\times0.075$$

$$=2.8\times10^{-4}\text{ J}$$

68. (a)



Buoyant force + surface tension = mg

$$\sigma\frac{V}{2}g+2\pi RT=\rho Vg$$

$$2\pi RT=\frac{(2\rho-\sigma)}{2}\frac{4}{3}\pi R^3g;\left[V=\frac{4}{3}\pi R^3\right]$$

$$2\pi RT=\frac{(2\rho-\sigma)}{2}\frac{4}{3}\pi R^3g;\left[V=\frac{4}{3}\pi R^3\right]$$

$$R^3=\frac{3T}{(2\rho-\sigma)g}$$

$$\Rightarrow R=\sqrt{\frac{3\times7.5\times10^{-2}\,N-m^{-1}}{(2\rho-\sigma)\times10}}$$

$$R=\frac{3}{20\sqrt{(2\rho-\sigma)}}\text{m}=\frac{15}{\sqrt{2\rho-\sigma}}\text{cm}$$

69. (c) Initial surface energy = TA

Where T is surface tension and A is surface area

@FAKE_CBSE_X @RAJ_EDUNET

$$U_i = \left(\frac{75\times10^{-3}}{10^{-2}}\frac{N}{m}\right)\times\left[4\pi\left(1\times10^{-2}\right)^2\right]$$

$$= 75\times10^{-3}\times4\pi\times10^{-4} = 942\times10^{-7}\,J$$

To get final radius of drops by volume conservation

$$\frac{4}{3}\pi R^3 = 729\left(\frac{4}{3}\pi r^3\right)$$

R = Initial radius

r = final radius

$$r = \frac{R}{(729)^{1/3}} = \frac{R}{9} = \frac{1}{9}\text{cm}$$

Final surface energy

$$U_f = 729[TA]$$

$$= 729\left[\frac{75\times10^{-3}}{10^{-2}}\frac{N}{m}\right]\times\left[4\pi\left(\frac{1}{9}\times10^{-2}\right)^2\right]$$

$$= 729\left[75\times10^{-3}\times\frac{4\pi\times10^{-4}}{81}\right]$$

$$= 9\left[942\times10^{-7}\,J\right]$$

Gain in surface energy

$$DU = 9\times942\times10^{-7} - 942\times10^{-7}$$

$$= 8\times942\times10^{-7}\,J = 7536\times10^{-7}\,J$$

$$= 7.5\times10^{-4}J$$

70. (*a*) Since volume is constant,

Let the number of drops be n

$$n\times\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \Rightarrow R^3 = nrr^3 \quad \ldots(i)$$

Decrease in surface area $= n\times4\pi r^2 - 4\pi R^2$

$$(\Delta A) = 4\pi\left[nr^2 - R^2\right] = 4\pi\left[\frac{n\times r^3}{r} - R^2\right]$$

$$= 4\pi\left[\frac{R^3}{r} - R^2\right] = 4\pi R^3\left[\frac{1}{r} - \frac{1}{R}\right]$$

Energy released

$$(W) = T\times\Delta A = 4\pi R^3 T\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\text{Heatproduced}\,(Q) = \frac{W}{J} = \frac{4\pi TR^3}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$$

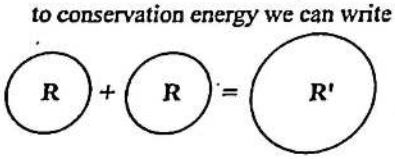
Now, $Q = ms\,\Delta\theta$

$$\Rightarrow \frac{4\pi R^3 T}{J}\left[\frac{1}{r} - \frac{1}{R}\right] = \left(\frac{4}{3}\pi R^3\right)\times1\times\Delta\theta$$

$$\Rightarrow \Delta\theta = \frac{3T}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$$

71. (*a*) Total surface energy before coalesce $= U_i = 2\times4\pi R^2\times\sigma = 8\pi R^2\sigma \quad \ldots(i)$

Let new radius becomes r, so according to conservation energy we can write



$$2\times\frac{4\pi R^3}{3} = \frac{4\pi r^3}{3} \Rightarrow r = 2^{\frac{1}{3}}R$$

Total surface energy after coalesce

$$= U_f = 4\pi r^2\times\sigma = 2^{\frac{2}{3}}\times4\pi R^2\sigma \quad \ldots(ii)$$

From equation (*i*) and (*ii*)

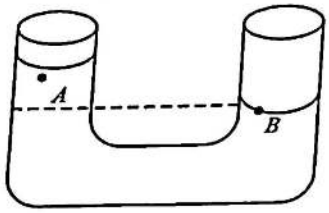
$$\Rightarrow \frac{U_i}{U_f} = \frac{8\pi R^2\sigma}{2^{\frac{2}{3}}\times4\pi R^2\sigma} = 2^{\frac{1}{3}}:1$$

72. (*a*) From Bernoulli's theorem,

$$P_B - P_A = \rho gh$$

$$\left(P_0 - \frac{2T}{r_2}\right) - \left(P_0 - \frac{2T}{r_1}\right) = \rho gh$$

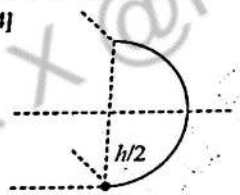
$$h = \frac{2T\left(\frac{1}{r_1} - \frac{1}{r_2}\right)}{\rho g}$$



$$= \frac{2\times7.3\times10^{-2}\times\left(\frac{1}{2.5\times10^{-3}} - \frac{1}{4\times10^{-3}}\right)}{1000\times10}$$

$$= 2.19\times10^{-3}\text{m} = 2.19\text{ mm}$$

73. [3.74]



Pressure at the bottom of disc = pressure due to surface tension

$$\rho gh = T\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$R_1 >>> R_2$

So $\frac{1}{R_1} <<< \frac{1}{R_2}$ and $R_2 = h/2$

$$\therefore \rho gh = T\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = T\left(0 + \frac{1}{h/2}\right)$$

$$h^2 = \frac{2T}{\rho g}$$

$$h = \sqrt{\frac{2T}{\rho g}} = \sqrt{\frac{2\times0.07}{10^3\times10}} = \sqrt{\frac{14\times100}{10^4\times100}}$$

$$h = \sqrt{14}mm = 3.741$$

74. (*c*) Surface tension will be less as temperature increases

$$h = \frac{2T\cos\theta}{\rho gr}$$

Height of capillary rise will be smaller in hot water and larger in cold water.

When a capillary tube is immersed in hot water, it expands. Therefore, its radius increases. As 'T' decreases and 'r' increases, therefore, the height of capillary rise (h) will be smaller in hot water than in cold water.

75. [3] since contact angle depends on cohesive and adhesive forces therefore statement I is correct.

Height of liquid is given by $h = \frac{2T\cos\theta}{\rho gr}$,

Statement II is incorrect.

Tube (assuming length of capillary is sufficient) Hence option (3) is correct.

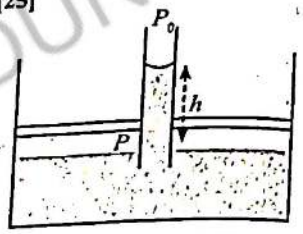
76. (*a*) By using, $h = \frac{2T\cos\theta}{\rho gr}$;

If $\theta = 0°$ then rise is non-zero

Statement-1 is incorrect.

Contact angle depends on adhesive & cohesive forces hence material.

77. [25]



$$h_0 = \frac{2T\cos\theta}{\rho gr} = \frac{2\times0.075\times1}{10^3\times10\times10^{-4}} = 15\,\text{cm}$$

As the process is isothermal: $P_0V_0 = PV$

$$P_0V_0 = P\frac{100V_0}{101} \Rightarrow P = \frac{101}{100}P_0$$

Using pressure equation.

$$P_0 - \frac{2T\cos\theta}{r} + \rho gh = P = \frac{101}{100}P_0$$

$$\Rightarrow -\rho gh_0 + \rho gh = \frac{P_0}{100}$$

$$\Rightarrow h = h_0 + \frac{P_0}{100\rho g}$$

$$\Rightarrow h = 15 + \frac{10^5}{100\times10^3\times10}$$

$$= 15 + 10 = 25\text{ cm}$$

78. (*c*)

$$h = \frac{2S\cos\theta}{r\rho g}$$

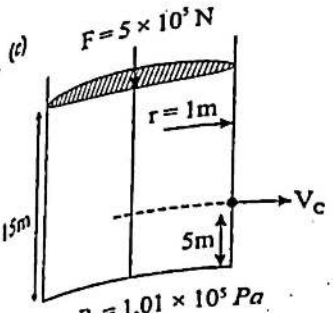
$$\therefore \frac{h_1}{h_2} = \frac{S_1}{S_2}\frac{\rho_2}{\rho_1}$$

$$\frac{5}{h_2} = \left[\frac{1}{2}\right]\left[\frac{2}{1}\right] \Rightarrow h_2 = 5cm = 0.05m$$

{Info about angle of contact not there so most appropriate is 3 }

@FAKE_CBSE_X_@RAJEDUNET

79. (c)



We have, $P_0 = 1.01 \times 10^5\ Pa$

$\rho_w = 1000\ kg/m^3$

$g = 10 m/s^2$

Applying bernaulli's eqn

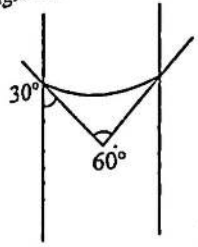
$$\frac{5\times10^5}{\pi}+\rho g\times10=\rho_0+\frac{1}{2}\rho V_e^2$$

$$\Rightarrow \frac{5}{3.14}\times10^5+10^5-1.01\times10^5=\frac{1}{2}\rho V_e^2$$

$$\Rightarrow (1.6+1-1.01)\times10^5=500V_e^2$$

$$V_e=\sqrt{\frac{1.59\times10^5}{500}}=\sqrt{318}=17.8 m/s$$

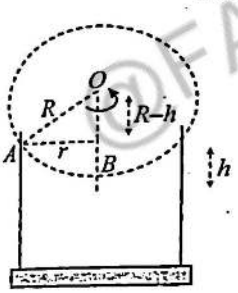
80. (b) Angle of contact = 30°



$$h=\frac{2T\cos\theta}{r\rho g}=\frac{2\times0.05\times\left(\frac{\sqrt{3}}{2}\right)}{0.15\times10^{-3}\times667\times10}$$

$$=0.087\ m$$

81. (a,d)



In ΔOAB

$R^2=(R-h)^2+r^2$

$R^2=R^2-2hR+h^2+r^2$

$\Rightarrow 2hR=h^2+r^2$

$$\Rightarrow R=\frac{h^2+r^2}{2h}$$

Now considering equation of surface

$$y=y_0+\frac{\omega^2r^2}{2g}$$

$$h=\frac{\omega^2r^2}{2g}$$

Now using: $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$

$$\Rightarrow \frac{1}{v}+\frac{4}{3(H-h)}=\frac{1-4/3}{-R}$$

$$\Rightarrow \frac{1}{v}=\frac{1}{3R}-\frac{4}{3H} \Rightarrow \frac{1}{v}=\frac{2h}{3r^2}-\frac{4}{3H}$$

$$\Rightarrow \frac{1}{v}=-\frac{4}{3H}\left[1-\frac{\omega^2H}{4g}\right]$$

$$\Rightarrow v=\frac{3H}{4}\left[1+\frac{\omega^2H}{4g}\right]^{-1}$$

82. (a) $v_T \propto r^2$

$\sqrt{2gh} \propto r^2$

$\Rightarrow h \propto r^4$

83. (d) Using capillary rise equation:

$$h=\frac{2T\cos\theta_c}{\rho rg}$$

So, $h \propto \frac{1}{r}$

As radius becomes double height become half

New mass, $M' = \pi(2r)^2 (h/2) \times \rho = 2M$.

84. (d) Here, we have,

$$h_{Hg}=\frac{2S_1\cos\theta}{r_1\rho_1 g}$$

$$h_{water}=\frac{2S_2\cos\theta_2}{r_2\rho_2 g} \Rightarrow \frac{r_1}{r_2}=\frac{2}{5}$$

Hence, option (d) is correct answer.

85. (a,c,d)

$$h=\frac{2T\cos\theta}{\rho gR};\ h_1=\frac{2\times0.075\times\cos0°}{1000\times10\times0.2\times10^{-3}}$$

$\Rightarrow h_1 = 75$ mm (in T_1)

[If we assume entire tube of T_1]

$$\Rightarrow h_2=\frac{2\times0.075\times\cos60°}{1000\times10\times0.2\times10^{-3}}$$

= 37.5 mm (in T_2)

[If we assume entire tube of T_2]

Option (a): Since contact angles are different so correction in the height of water column raised in the tube will be different in both the cases, so option (a) is correct

Option (b): If joint is 5 cm is above water surface, then lets say water crosses the joint by height h, then:

$$\Rightarrow P_0-\frac{2T}{r}+\rho gh+\rho g\times5\times10^{-2}=P_0$$

$$\Rightarrow \cos\theta=\frac{R}{r},\ r=\frac{R}{\cos\theta}$$

$$\Rightarrow \rho g(h+5\times10^{-2})=\frac{2T\cos\theta}{R}$$

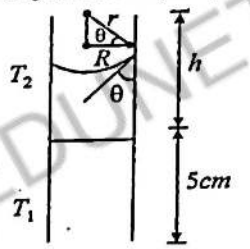
$$\Rightarrow h=\frac{2\times0.075\times\cos60}{0.2\times10^{-3}\times1000\times10}-5\times10^{-2}$$

$\Rightarrow h$ = –ve, not possible, so liquid will not cross the interface, but angle of contact at the interface will change, to balance the pressure,

So option (b) is wrong.

Option (c): If interface is 8 cm above water then water will not even reach the interface, and water will rise till 7.5 cm only in T_1, so option (c) is right.

Option (d): If interface is 5 cm above the water in vessel, then water in capillary will not even reach the interface. Water will reach only till 3.75 cm, so option (d) is right.



86. [2] Radius of smaller bubble, $r_1 = 3$cm

Radius of bigger bubble, $r_2 = 6$ cm

Pressure difference between P_2 & P_0.

$$P_2-P_0=\frac{4T}{6}$$

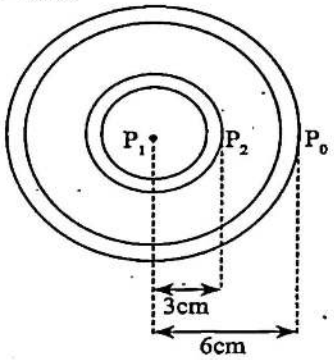
Pressure difference between P_1 & P_2.

$$P_1-P_2=\frac{4T}{3}$$

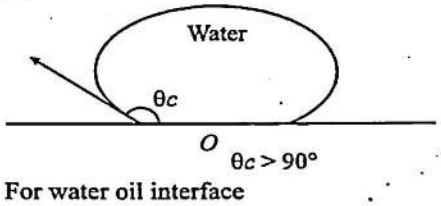
Pressure difference between P_1 & P_0.

$$P_1-P_0=\frac{4T}{2}=\frac{4T}{r}$$

$r = 2$cm



87. (a)



For water oil interface

@FAKE_CBSE_X @RAJ_EDUNET

88. (b) $P_1 - P_0 = \frac{4T}{a}$

$P_2 - P_0 = \frac{4T}{b}$

Resultant of excess pressure inside soap bubble,

$p = P_1 - P_2 = 4T\left(\frac{1}{a} - \frac{1}{b}\right)$

$= \frac{4T}{r} = 4T\left(\frac{1}{a} - \frac{1}{b}\right) \Rightarrow r = \frac{ab}{b-a}$

89. [25] $4t = 100 \times \frac{4}{3}\pi \times \frac{3}{40\pi} \times 10^{-9} \times 0.01$

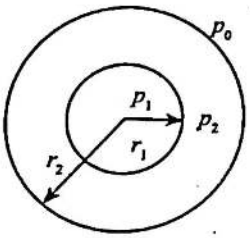
$\Rightarrow t = 2.5 \times 10^{-11}$ cm $= 25 \times 10^{-14}$ m.

90. [2] Excess pressure inside the smaller bubble

$p_1 - p_2 = \frac{4T}{r_1}$ ... (i)

Excess pressure inside the bigger bubble

$p_2 - p_0 = \frac{4T}{r_2}$ ... (ii)



Excess pressure inside the equivalent soap bubble

$p_1 - p_0 = \frac{4T}{r_{eq}}$

(i) + (ii),

$p_1 - p_0 = 4T\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$

$\frac{4T}{r_{eq}} = 4T\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$

$r_{eg} = \frac{r_1 r_2}{r_1 + r_2} = \frac{3 \times 6}{3+6} = 2cm$

91. (d) $P_1 = P_0 + \frac{4T}{r_1} \Rightarrow P_2 = P_0 + \frac{4T}{r_2}$

$\frac{r_1}{r_2} = 2 \Rightarrow \frac{V_1}{V_2} = 8$

92. (d) $\frac{4}{3}\pi r^3 \rho_w g - mg = ma$

$\Rightarrow m = \frac{\frac{4}{3}\pi r^3 \rho_w g}{g + a} = 4.15$ gm

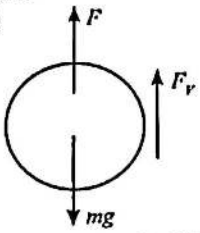
93. (*) $V = kt = \frac{4}{3}\pi R^3$

$R = \left(\frac{3k}{4\pi}t\right)^{1/3} \Rightarrow R = R_0(t)^{1/3}$

$P_{in} = P_{atm} + \frac{4T}{R} \Rightarrow P_{atm} + \frac{4T}{R_0(t)^{1/3}}$

None of the given graph is matching with the above explanation. So this question is bonus.

94. (b)



Balance equation for FBD diagram is,

$mg - F_B - F_v = ma$

$\left(\rho\frac{4}{3}\pi r^3\right)g - \left(\rho_L\frac{4}{3}\pi r^3\right)g - 6\pi\eta r v = m\frac{dv}{dt}$

Let $\frac{4}{3m}\pi R^3 g(\rho - \rho_L) = K_1$ and

$\frac{6\pi\eta r}{m} = K_2$

$\frac{dv}{dt} = K_1 - K_2 V$

Integrating the above equation,

$\int_0^v \frac{dv}{K_1 - K_2 v} = \int_0^t dt$

$-\frac{1}{K_2}\ln[K_1 - K_2 v]_0^v = t$

$\ln\left(\frac{K_1 - K_2 V}{K_1}\right) = -K_2 t$

$K_1 - K_2 V = K_1 e^{-K_2 t}$

Velocity,

$v = \left(\frac{K_1}{K_2}\right)\left(1 - e^{-K_2 t}\right)$

(v-t graph will exponentially increase)

95. (b) Gases have low viscosity.

Surface tension decreases due to insoluble impurities like detergent

96. (a) In this case, byuoyancy force will be negligible as given density is negligible.

We know, terminal velocity,

$Mg = 6\pi\eta r v$

$V \propto \frac{1}{r}$ (Given mass is constant)

Now, $\frac{v}{v'} = \frac{r'}{r}$

$r' = 2r$

So, $v' = \frac{v}{2}$

97. [4] $F_{net} = 0$

$mg - F_B - F_v = 0$

$\therefore$ For constant velocity, $F_{net} = 0$

$F_v = mg - v\rho_0 g = mg - \frac{m}{\rho}\rho_0 g = mg\left(1 - \frac{\rho_0}{\rho}\right)$

98. [40] m and M is the mass of the small and bigger drops respectively,

$8 \propto m = M$

$8r^3 = R^3 \Rightarrow R = 2r$

The terminal velocity of the drop, as $V_T \propto r^2$

Radius double so V_T becomes 4 time

$\therefore 4 \times 10 = 40$ cm/s

99. (c) velocity when the ball enters into the water

$V_T = \frac{2g}{9}\frac{R^2[\rho_B - \rho_L]}{\eta}$

$\Rightarrow V_T = \frac{2}{9} \times \frac{10 \times \left(10^{-4}\right)^2}{9.8 \times 10^{-6}}\left[10^3 - 10^3\right]$

$\Rightarrow V_T = 224.5$

when the ball just reaches the surface of water,

$V = \sqrt{2gh}$

$h = \left(\frac{V^2}{2g}\right) = 2518$ m

100. [7] When the ball falls with terminal velocity

$F_v = (mg - F_B) = V\sigma_b g - V\rho_\ell g$

$= \frac{4}{3}\pi\left(10^{-3}\right)^3 \times 9.8(10.5 - 1.5) \times 10^3$

$= 3696 \times 10^{-7}$ N

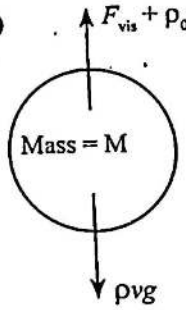
So, $x = 7$

101. [25] $|F| = \eta A\frac{\Delta v}{\Delta x} \Rightarrow 0.1$

$= 5 \times 10^{-3} \times 0.2 \times \frac{v}{0.25 \times 10^{-3}}$

$\Rightarrow v = 25 \times 10^{-3}$ m/s

102. (a)



For constant velocity, net force on ball should be zero

$F_{net} = 0$

$F_{vis} + \rho_0 vg - \rho vg = 0$

$F_{vis} = (\rho - \rho_0)vg$

$F_{vis} = \rho vg\left(1 - \frac{\rho_0}{\rho}\right)$

$F_{vis} = Mg\left(1 - \frac{\rho_0}{\rho}\right)$

@FAKE_CBSE_@RAJ_EDU.NET

102. [10]

As speed is constant so the force acting on it is zero.

$B = F_v$

$\frac{4}{3}\pi R^3 \rho g = 6\pi\eta R v \Rightarrow \eta = \frac{2R^2\rho g}{9v}$

$\eta = \frac{2\times\left(3\times10^{-3}\right)^2\times1750\times10}{9\times0.35\times10^{-2}} = 10 Pas$

104. (c) A. Torque $[\tau] = [F][r_\perp]$

$[\tau] = [MLT^{-2}]\,[L] \Rightarrow [ML^2T^{-2}]$

B. $[\text{Stress}] = \frac{[F]}{[A]} = \frac{MLT^{-2}}{L^2} = [ML^{-1}T^{-2}]$

C. $[\text{Pressure gradient}] = \frac{[\Delta P]}{[\Delta X]}$

$= \frac{[ML^{-1}T^{-2}]}{L} \Rightarrow [ML^{-2}T^{-2}]$

D. Coefficient of viscosity $\Rightarrow F = 6\pi\eta r v$

$[\eta] = \frac{[F]}{[r][v]} = \frac{[MLT^{-2}]}{[L][LT^{-1}]}$

$[\eta] = ML^{-1}T^{-1}$

105. (b) From $v = \frac{2r^2(\rho-\delta)g}{g}\frac{}{\eta}$,

Let the radius of small drop be r_1 and bigger drop be r_2.

$\frac{v_1}{v_2} = \left(\frac{r_1}{r_2}\right)^2$

Volume of 8 equal drops = Volume of new drop

$8\times\frac{4}{3}\pi r_1^3 = \frac{4}{3}\pi r_2^3$

$r_2 = 2r_1$

$\frac{10}{v_2} = \left(\frac{1}{2}\right)^2$

$v_2 = 40$ cm/s

106. (c) Formula of terminal velocity

$v_T = \frac{2}{9}\frac{r^2(\rho-\delta)g}{\eta}$

$v_T \propto r^2$

107. [100] $F = \eta A\frac{\Delta v_x}{\Delta y}$

$\frac{F}{A} = \eta\frac{\Delta v_x}{\Delta y}$

$\Rightarrow 10^{-3} = 10^{-2}\times\frac{36\times1000}{h\times3600}$

$\Rightarrow h = 10^{-2}\times\frac{36\times1000}{10^{-3}\times3600} = 100\,\text{m}$

108. (b) $F_v = mg - FB$

$= mg - \left(\frac{m}{d_1}\times d_2\right)g = mg\left(1-\frac{d_2}{d_1}\right)$

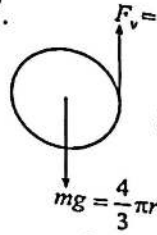
109. (c) Coefficient of viscosity, $\eta = [ML^{-1}T^{-1}]$

Pressure × time =

$\frac{Ft}{A} = [MLT^{-2}][T][L^{-2}] = [ML^{-1}T^{-1}]$

$F_{\text{viscous}} = -\eta A\frac{\Delta v}{\Delta y}$

110. (d)



$mg = \frac{4}{3}\pi r^3\rho g$

$6\pi\eta r v_t = \frac{4}{3}\pi r^3\rho g$

$v_t = \frac{2}{9}\times\frac{\rho r^2 g}{\eta}$

$= \frac{2\times10^{-12}\times10^3\times10}{9\times1.8\times10^{-5}} = 123.4\times10^{-6}\,m/s$

111. [20] Speed after falling through height h Should be equal to terminal velocity

$\sqrt{2gh} = \frac{2}{9}\frac{r^2(d-\rho)g}{\eta}$

$\sqrt{2gh} = \frac{2}{9}\frac{10^{-8}(10000-1000)\times10}{10^{-5}}$

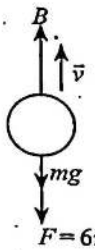
$= \frac{2}{9}\times10^{-8}\frac{9\times10^4}{10^{-5}} = 20$

$2\times10\times h = 400$

$h = 20$ m

112. [11] Because of density of air, the value of mg can be neglected.

$\therefore B = F$



$F = 6\pi\eta r v$

$\Rightarrow \left(\frac{4}{3}\pi r^3\right)\rho g = 6\pi n r v \Rightarrow \eta = \frac{2r^2\rho g}{9v}$

$= \frac{2\times\left(10^{-3}\right)^2\times1750\times10}{9\times0.35\times10^{-2}} = \frac{10}{9} Pa-S \approx 11$ poise

113. [25] We have, $m = 0.3$g, $\rho_{(\text{ball})} = 8$g/cc

$\therefore V = \frac{m}{\rho} = \frac{0.3}{8}cc$

$\rho_{\text{glycerene}} = 1.3$g/ $cc = 1.3\times10^3$kg/m^3

$F_v + F_B = mg$

$\Rightarrow F_v = .3\times10^{-3}\times10 - 1.3\times\frac{0.3}{8}\times10^{-6}\times10\times10^3$

$= 25\times10^{-4}\,N$

$\therefore x = 25$

114. (a) At terminal speed

$Mg = Fv = 6\pi\eta R v$

$\Rightarrow v = \frac{mg}{6\pi\eta R}$

$v = \frac{\delta\times\frac{4}{3}\pi R^3 g}{6\pi\eta R}$

$= \frac{2\times\delta R^3\times g}{9\eta}$

$= \frac{2\times1000\times\left(0.2\times10^{-3}\right)^3\times10}{9\times1.8\times10^{-5}}$

$= \frac{400}{81} = 4.94 m/s$

115. (d) According to the question, Viscous force = Weight

$\Rightarrow F_v = \rho\times\frac{4}{3}\pi r^3\times g = 3.9\times10^{-10}\,N$

116. (a,b,c) $n_1 >> (n_1 - n_2) = \Delta n$

$p_1 = \frac{n_1 RT}{N_A}\quad p_2 = \frac{n_2 RT}{N_A}$

$F = (n_1 - n_2)k_B TS = \Delta n k_B TS$ ...(a)

$V = \frac{\Delta n k_B TS}{\beta}$

Force balance $\Rightarrow$ Pressure × Area = Total number of molecules × βv

$\Delta n k_B TS = \Delta n_1 S\beta v$

$\Rightarrow n_1\beta v\ell = \Delta n k_B T$ ...(b)

Total number of molecules/sec

$= \frac{(n_1 v\,dt)S}{dt}$

$= n_1 vS = \frac{\Delta n k_B T v S}{\beta v\ell}$

$= \left(\frac{\Delta n}{\ell}\right)\left(\frac{k_B T}{\beta}\right)S$ ...(c)

As Δn will decrease with time therefore rate of molecules getting transfer decreases with time.

117. (c) As mass of the sphere is same

$\therefore \rho\frac{4}{3}\pi R^3 = 27\cdot\frac{4}{3}\pi r^3\rho \Rightarrow r = \frac{R}{3}$

Now, $V_T = \frac{2}{9}\frac{r^2}{h}(r_0 - r_\ell)g$

$\Rightarrow V_T \propto r^2$

$\therefore \frac{V_1}{V_2} = \frac{R^2}{r^2} = \frac{R^2}{\frac{R^2}{9}} = \frac{9}{1}$

@FAKE_CBSE @RAJ EDUNET

1. (b) $h_1+h_2=0.29\times2+0.1$

$h_1+h_2=0.68$ ...(i)

$\Rightarrow P_0+\rho_k g(0.1)+\rho_w g(h_1-0.1)$

[ρ_k = density of kerosene and ρ_w = density of water]

$-\rho_w g h_2=P_0$

$\Rightarrow \rho_k g(0.1)+\rho_w g h_1-\rho_w g\times(0.1)=\rho_w g h_2$

$\Rightarrow 800\times10\times0.1+1000\times10\times h_1-1000\times10\times0.1=1000\times10\times h_2$

$\Rightarrow 10000(h_1-h_2)=200$

$\Rightarrow h_1-h_2=0.02$ ...(ii)

$\Rightarrow h_1=0.35$

$\Rightarrow h_2=0.33$

So, $\frac{h_1}{h_2}=\frac{35}{33}$

2. (b) As there is no exchange of heat, process is adiabatic

Applying

$T_p\frac{1-r}{r}=\text{constant}$

$T_2P_2\frac{1-r}{r}=T_1P_1\frac{1-r}{r}$

$T_2=T_1\Rightarrow\left(\frac{P_1}{P_2}\right)^{\frac{1-r}{r}}=T_1\left(\frac{P_2}{P_1}\right)^{\frac{1-r}{\gamma}}$

Substituting the value we have

$T_2=T_0\left[\frac{P_0+\rho_l g(H-y)}{P_0+\rho_l gH}\right]^{\frac{5/3-1}{5/3}}$

$T_2=T_0\left[\frac{P_0+\rho_{lg}(H-y)}{P_0+\rho_{lgH}}\right]^{2/5}$

3. (a) All the gas molecules inside the compartment experience the same force and hence the pressure will be the same everywhere horizontally and since gravity is neglected so pressure down the compartment will also be the same.

4. (b) It is clear that the height of liquid column I in right limb is $(h+2)$cm and the height of liquid column II in left limb is 2.0 cm and of liquid column I is h cm.

$\therefore 2\times\rho_2\times g+h\times1.1\times g=(2+h)\times1.1\times g$

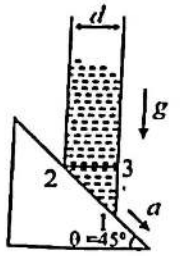
$\Rightarrow 2\rho_2=2.2$

$\Rightarrow \rho_2=1.1$

5. (a,c) $P_1-P_3=\rho\left(g-\frac{a}{\sqrt{2}}\right)d$

$P_2-P_3=\rho\frac{a}{\sqrt{2}}d$

$\therefore P_1-P_2=\rho d\left[g-\frac{2a}{\sqrt{2}}\right]$

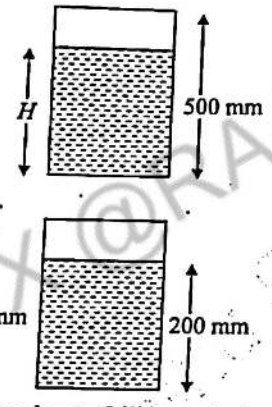


$\therefore \frac{P_1-P_2}{\rho gd}=\left[1-\sqrt{2}\frac{a}{g}\right]=\beta$

$\therefore$ if $\beta=0$, $a=\frac{g}{\sqrt{2}}$ ...(a)

$\beta=\frac{\sqrt{2}-1}{2}$, $a=\frac{g}{2}$ ...(b)

6. [6] As,



Pressure due to falling water level at 200 mm is

$P+\rho gh=P_0$

or $P=10^5-(1000)(10)(0.2)$

$=98\times10^3$ N/m^3

Now, $P_0V_0=PV$

or $10^5[A(0.5-H)]$

$=98\times10^3[A(0.5-0.2)]$

where A = cross-sectional area of a vessel.

$0.5-H=0.294$

$\Rightarrow H=0.206$ m $=206$ m

The fall in height (in mm) of water level $=206-200=6$ mm

7. [2.95] Let P_0 be the initial pressure, P_1, P_2 be the pressures in the bottom and top air sections after being held vertical. Let x be the displacement of the mercury section once held vertical.

Since PV is constant for each section of the air,

$P_1=\frac{45}{45-x}P_0$ and $P_2=\frac{45}{45+x}P_0$

Considering the equilibrium in the tube once held perpendicular,

$P_1A=P_2A+mgl=P_2A+\rho(10)gA$

$\Rightarrow P_1-P_2=10\rho g$

and $P_0=76\rho g$

Therefore, $x=2.95$ cm

8. [False] Since the volume of mercury increases, the density of mercury decreases. Now more height of the liquid will be required to balance the atm pressure.

9. [False] It is due to convection currents in the water. It will circulate in a clockwise direction.

10. Weight of liquid of height

$H=\frac{\pi d^2}{4}\times H\rho\times g\rightarrow$ ...(i)

Let us consider a mass dm situated at a distance X from A as shown in the figure. Centripetal force required for the mass to rotate $=(dm)\omega^2$

$\therefore$ The total centripetal force required for the mass of length L to rotate

$=\int_0^l\left(\rho x\frac{\pi d^2}{4}\right)xdx\times\left(x\omega^2\right)$ ...(ii)

$=\rho\times\frac{\pi d^2}{4}\times\omega^2\times\frac{l^2}{2}\rightarrow$

This centripetal force required is provided by the weight of liquid of height 'H'.

From (i) and (ii)

$\frac{\pi d^2}{4}\times H\times\rho\times g=\rho\times\frac{\pi d^2}{4}\times\omega^2\times\frac{l^2}{2}$

$\Rightarrow H=\frac{\omega^2l^2}{2g}$

11. Work done by gravity

$=-$(change in potential energy)

Assuming final equilibrium is h

$W_{\text{Cylinder}}=U_i-U_f$

$W_{\text{cylinder1}}=Apg\frac{h_1}{2}(h_1-h)$

$W_{\text{cylinder2}}=Apg\frac{h_2}{2}(h_2-h)$

Total work done by gravity

$(W_g)=W_{\text{cylinder1}}+W_{\text{cylinder2}}$

$\Rightarrow W_g=Apg\frac{h_1}{2}(h_1-h)+Apg\frac{h_2}{2}(h_2-h)$

Using volume conservation

$h=\frac{h_1+h_2}{2}$

@RAKE_CBSE_X@RAJ_EDUNET

$$W'_g = Apg\frac{h_1}{2}\left[h_1 - \left(\frac{h_1+h_2}{2}\right)\right] + Apg\frac{h_2}{2}\left[h_2 - \left(\frac{h_1+h_2}{2}\right)\right]$$

$$W'_g = Apg\left(\frac{h_1-h_2}{2}\right)^2$$

12. (a) Let V_w be volume occupied by water in the shell
V'_a be volume occupied by air in the shell
V'_m be volume occupied by material in the shell

$$\frac{V'_m+V'_a+V_w}{2}\rho_w g = V_m\rho_c\rho_w g + V_w\rho_w g$$

Now, $V_w = V_m(1-2\rho_c) + V_a$

$$\rho_c > \frac{1}{2} \Rightarrow V_w < V_a$$

$$\rho_c > \left\langle \frac{1}{2} \Rightarrow V_w \right\rangle < V_a$$

13. (d) Considering the fact that the density of coins is very high in comparison to water and wood.
Density of the coin is more so it was applying considerable force on wood before falling in water. But once it'll fall, wood can't apply same force alone so wood will come a little up as result L will decrease.
When a coin falls in water wood goes up so displaced volume decreases and coin has high density so its volume is low and it doesn't displace liquid that much. As a result, H will also decrease.

14. (d) The net upward force on the bottom of the cylinder = weight of the liquid displaced by cylinder + thrust on the upper surface of cylinder due to h column of liquid

$$F_{net} = V\rho g + h\rho g \times \pi r^2 = \rho g(V + \pi R^2 h)$$

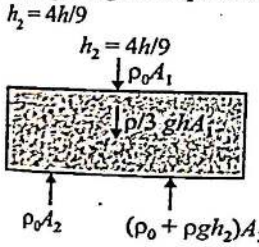
15. (c) The mass of sphere be $m = dv$, where d is density and v is volume.
So we have $m = M_0 + m_m$

$$\Rightarrow dv = d_0 \times \frac{v}{2} + d_m \times \frac{v}{2}$$

$$\Rightarrow d = \frac{d_0+d_m}{2}$$

$$\Rightarrow d = \frac{0.8+13.6}{2} = 7.2$$

16. (a) On equating the required forces, we get
$h_2 = 4h/9$



17. (a) When the beaker is allowed to fall freely, the apparent weight of the body becomes zero.
i.e. The body exerts no force on water. Hence no water is displaced due to the weight of the body. So buoyant force i.e. upthrust will also become zero.

18. (c) As we know that due to acceleration in the forward direction, a vessel is an accelerated frame. Thus, a pseudo force 'ma' will be exerted in the backward direction. Therefore, water will be displaced in the backward direction.

19. (c) Since, it is given that the coefficient of cubical expansion of alcohol is more than that of the metal.
This statement means that when we raise the temperature, the volume of alcohol increases at a faster rate than as compared to the increase in volume of metal ball.
OR in other words, the density of alcohol decreases at a faster rate as compared to metal ball. As a result, the metal ball experiences a lesser buoyant force as the temperature is raised. Hence, the weight at increased temperatures would be more.
Hence, answer should be $W_1 < W_2$.

20. (b) Buoyancy force
F = (Volume of Bubble)(ρ_l)

$$g = \left(\frac{nRT_2}{p_2}\right)\rho_l g$$

Here, $T_2 = T_0\left[\frac{p_0+\rho_e g(H-y)}{p_0+\rho_l gh}\right]^{2/5}$ and
$p_2 = p_0 + \rho_l g(H-y)$
Substituting the values, we get

$$F = \frac{\rho_l nRgT_0}{(p_0+\rho_l gH)^{2/5}\left[p_0+\rho_l g(H-y)\right]^{3/5}}$$

$\therefore$ Correct option is (b)

21. (a, d) Weight of the balls i.e system = mg

$$= \left[\rho\times\frac{4}{3}\pi R^3 + 3\rho\times\frac{4}{3}\pi R^3\right]g$$

$$w = \frac{16\rho\pi R^3 g}{3}$$

Buoyant force = $V\rho g$
$\rho_l = 2\rho = V = 2\rho g$
Buoyant force = weight of system

$$V.2\rho g = \frac{16\rho\pi R^3 g}{3}$$

$$V = \frac{8\pi R^3}{3}$$

Submerged volume $= \frac{8\pi R^3}{3}$

Total volume of system $= \frac{4\pi}{3}R^3 + \frac{4\pi}{3}R^3$

$$= \frac{8\pi R^3}{3}$$

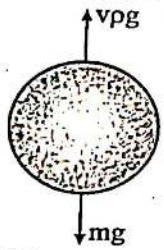
Total volume = submerged volume; it means both spheres are submerged completely. For spring elongation, on sphere of density

$$Kx + \frac{4\pi}{3}R^3\times\rho\times g = \frac{4\pi}{3}R^3\times 2\rho\times g$$

$$Kx = \frac{4\pi R^3\rho g}{3}[2-1] \Rightarrow x = \frac{4\pi R^3\rho g}{3K}$$

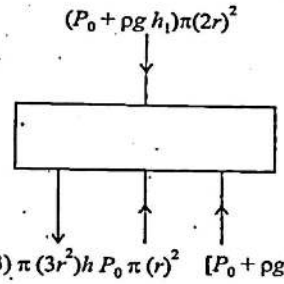
22. (b, c) Due to displacement of water in the beaker caused by the mass, the mass experiences an upward buoyant force, less in magnitude than the weight of the body. Hence the weight read by balance A is lesser than 2 kg.
Also, a reaction pair force of the buoyant force on mass acts on water downwards. Hence this force (<2 kg) adds to the weight of water, and the reading of balance B is between 3 kg and 5 kg.

23. [4]



$$480\times g = v\rho_l g$$
$$(480-N)g = v\rho_2 g$$
$$\frac{480-N}{480} = \frac{\rho_2}{\rho_1}$$
$$\left(1-\frac{N}{480}\right) = \frac{e^{-h_2/h_0}}{e^{-h_1/h_0}} = e^{\frac{h_1-h_2}{h_0}} = e^{\frac{50}{6000}}$$
$$1-\frac{N}{480} = 1-\frac{50}{6000} \Rightarrow N = \frac{50\times 480}{6000} = 4$$

24. (c) The block would start rising once in equilibrium with the pressure from liquid above and the weight of the block balances the forces from bottom.



@TAKE_CBSE_TO_IIT_FOUNDATION

Under equilibrium,

$$(P_0+\rho g h_1)\pi(2r)^2+\frac{\rho}{3}4\pi r^2 hg$$

$$=(P_0+\rho g(h_1+h_2))(\pi(2r)^2-\pi(r)^2)$$

Thus $h_1=\frac{5h}{3}$

25. (*a*) Buoyant force would decrease with further decrease in water level and thus block would not move up. The downwards forces would be balanced by the upward normal force on the block.

26. (*a*) Weight of cylinder = upthrust due to both liquids

$$V\times D\times g=\left(\frac{A}{5}\times\frac{3}{4}L\right)\times d\times g+\left(\frac{A}{5}\times\frac{L}{4}\right)\times 2d\times g$$

$$\Rightarrow\left(\frac{A}{5}\times L\right)\times D\times g=\frac{A\times L\times d\times g}{4}$$

$$\Rightarrow\frac{D}{5}=\frac{d}{4}$$

$$\therefore D=\frac{5}{4}d$$

27. Weight of metal piece $w_m=mg$

When immersed in liquid, let fraction f be submerged in the liquid.

$\therefore fV_{0m}\rho_{01}g=mg$ ...(*i*)

When the metal and the liquid are heated, let f' be the fraction which is submerged in the liquid.

$$\therefore f'V_{0m}(1+\gamma_m\Delta T)\rho_{01}(1-\gamma_1\Delta T)g=mg \quad ...(ii)$$

Dividing (*i*) by (*ii*),

$$\frac{f}{f'(1+\gamma_m\Delta T)(1-\gamma_1\Delta T)}=1$$

$$\Rightarrow\frac{f'}{f}=(1-\gamma_m\Delta T)(1+\gamma_1\Delta T)$$

$$\Rightarrow\frac{f'}{f}-1=(\gamma_1-\gamma_m)\Delta T$$

$$\frac{f'-f}{f}=(\gamma_l-\gamma_m)\Delta T=(\gamma_2-\gamma_1)\Delta T$$

28. [False] According to Archimedes principle if any object is floating on a liquid the weight of the liquid displaced is equal to the weight of the object, when the block of ice melts the bullet ultimately sink in water and displaces the same volume of water as its own volume was, but when it was embedded in the ice it displaced move volume, therefore level of water will fall.

29. (*a*) Liquid A is applying the hydrostatic force on the cylinder from all the sides. So, net force is zero.

(*b*) In equilibrium: Weight of cylinder = Net upthrust on the cylinder

Let s be the area of the cylinder, then weight

$=(s)(h+h_A+h_B)\rho_{cylinder}g$

and upthrust on the cylinder

= upthrust due to liquid A + upthrust due to liquid B.

$=sh_A\rho_Ag+sh_B\rho_Bg$

Equating these two

$s(h+h_A+h_B)\rho_{cylinder}g=sh_{A\rho A g}=h_A\rho_A+h_B\rho_B$

or $(h+h_A+h_B)\rho_{cylinder}=h_A\rho_A+h_B\rho_B$

Substituting $h_A=1.02$ cm, $h_B=0.8$ cm and $\rho_A=0.7$ g/cm^3

$\rho_B=1.02$ g/cm^3 and $\rho_{cylinder}=0.8$ g/cm^3

In the above equation, we get

$h=0.25$ cm

(*c*) Net upward force = extra upthrust

$=sh\rho_Bg$

$\therefore$ Net acceleration

$$a=\frac{\text{Force}}{\text{Mass of cylinder}}$$

$$a=\frac{h\rho_Bg}{(h+h_A+h_B)\rho_{cylinder}}$$

Substituting the values of h, $h_A h_B$, ρ_B and $\rho_{cylinder}$ we get

$a=\frac{g}{6}$ (upwards)

30. For the rod to float in liquid at equilibrium gravitational mass = Buoyant force

$(mg+\rho vg)=\sigma Vg$

$m+\rho V/\sigma V$

here $V=\pi R^2L$

$m=(\sigma-\rho)\pi R^2L$

minimum value of m is $(\sigma-\rho)\pi R^2L$.

31. (*a*) Let ρ be the density cylinder

Volume of fluid having density 'd' displaced

$$V_d=\frac{A}{5}\times\frac{3L}{4}=\frac{3AL}{20}$$

Volume of '$2d$' displaced

$$v_{2d}=\frac{A}{5}\times\frac{L}{4}=\frac{AL}{20}$$

Total Buoyant force exerted

$F_{Buo}=V_d\times d\times g+V_{2d}\times 2dg$

$$=\frac{3AL}{20}dg+\frac{2AL}{20}dg$$

$$=\frac{1}{4}ALdg$$

The cylinder remains in equilibrium

$F_{Buo}=F_{Weight}$

$$\frac{1}{4}ALdg=\rho\times\frac{A}{5}\times Lg$$

$$\frac{1}{4}d=\frac{\rho}{5}$$

$$\rho=\frac{5}{4}d$$

(*b*) The pressure at the bottom surface:

$$P=\frac{\text{Total weight of liquid + Solid}}{\text{Area of cross section of Container}}$$

$$P=\frac{\frac{A}{6}\left(\frac{dgh}{2}+\frac{2dgh}{2}+\frac{5dgL}{4}\right)}{\frac{A}{6}}$$

$$P=\frac{dg(6h-5L)}{4}$$

32. (*a*) In an elastic collision with the surface direction of velocity is reversed but magnitude remains the same. Therefore time of fall = time to rise.

or time of fall = $t_{1/2}$

So, the velocity of the ball just before colliding with liquid is

$$v=g\frac{t_1}{2}$$

Retardation inside the liquid

$$a=\frac{\text{upthrust}-\text{weight}}{\text{mass}}$$

$$=\frac{Vd_Lg-Vdg}{Vd}$$

$$=\left(\frac{d_L-d}{d}\right)g\,(V=\text{volume of ball})$$

Time taken by the ball to come to rest under this retardation will be

$$t=\frac{v}{a}=\frac{gt_1}{2a}$$

$$=\frac{gt_1}{2\left(\frac{d_L-d}{d}\right)}=\frac{dt_1}{2(d_L-d)}$$

the time taken to come back on the liquid surface will be the same. Therefore,

(*a*) t_2 is the time which the ball takes to came back to the position from where it was released.

$=t_1+2t$

$$=t_1+\frac{dt_1}{d_1-d}=t_1\left[1+\frac{d}{d_L-d}\right]$$

$$t_2=\frac{t_1d_L}{d_L-d}$$

(*b*) The motion of the ball is periodic but not simple harmonic because the acceleration of the ball is g in air and $\left(\frac{d_L-d}{d}\right)g$ inside the liquid which is

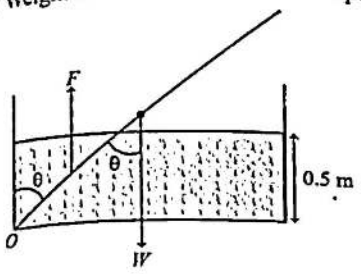
@FAKE_CBSE_@RAJEDUNET

not proportional to the displacement, which is a necessary and sufficient condition for SHM.

(c) When $d_L = d$, retardation or acceleration which is inside the liquid turns out to be zero (upthrust = weight). Therefore, the ball will carry on with constant velocity $v = gt_1/2$ inside the liquid.

33. The level of water will rise when stones are unloaded into the water.
The density of stones is more than the density of the water. So, when the stones are dropped into the water, the stone replaces the volume of water equal to the volume of stones.

34. Submerged length = 0.5 sec q, F = Upthrust, w = Weight
Three forces will act on the plank.
(a) Weight which will act at centre of plank.



(b) Upthrust which will act at centre of submerged portion.
(c) Force from the hinge at O.
Taking moments of all three forces about point O. Moment of hinge force will be zero.
$\therefore$ Moment of w (clockwise)
= Moment of F (anti-clockwise)

$$\therefore (\text{Alg}\,\rho)\frac{l}{2}\sin\theta$$

$$= A(0.5\sec\theta)(\rho_w)(g)\left(\frac{0.5\sec\theta}{2}\right)\sin\theta$$

$$\therefore \cos^2\theta = \frac{(0.5)^2(1)}{(l^2)(\rho)} = \frac{(0.5)^2}{(0.5)} = \frac{1}{2}$$

(as $l = 1$ m)

$$\therefore \cos\theta = \frac{1}{\sqrt{2}} \text{ or } \theta = 45^\circ$$

35. (a) We know, $A_1u_1 = A_2v_2$
$\Rightarrow u_1 = 0.1\,v_2$
Also

$$\rho_0 + \rho gh + \frac{1}{2}\rho u_1^2 = \rho_0 + \frac{1}{2}\rho v_2^2 + 0$$

$$gh = \frac{v_2^2 - u_1^2}{2} \Rightarrow 2gh = \frac{v_2^2\left(1-(0.1)^2\right)}{2}$$

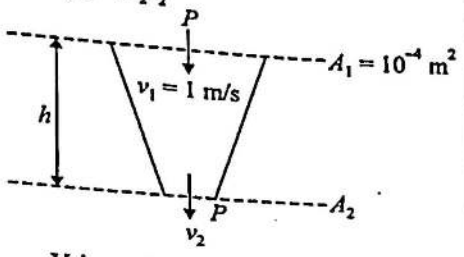
$$v_2^2 = \frac{(2)(10)(2.475)}{\left(1-(0.1)^2\right)}$$

$$v_2^2 = 50\,\text{m}^2/\text{s}^2$$

36. (a) By principle if continuity: $A_1V_1 = A_2V_2$
As per question: $A_1 = L_2$; $v_1 = \sqrt{2gy}$
and $A_2 = \pi R^2$, $v_2 = \sqrt{2g4y}$
So, $L^2\sqrt{2gy} = \pi R^2\sqrt{2g4y}$
$\Rightarrow L^2 = 2\pi R^2$

$$\Rightarrow R = \frac{L}{\sqrt{2\pi}}$$

37. (c) As by continuity eq.
$A_1v_1 = A_2v_2$



Volume flow rate = 10^{-4} m^3/sec

$$\Delta P = \rho gh = 10^3\,\frac{\text{kg}}{\text{m}^3} \times 10\,\frac{\text{m}^2}{\text{s}} \times 0.15$$

$$\Rightarrow \Delta P = 1500\ \text{Pa}$$

$$\Rightarrow \Delta P = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right)$$

$$\Rightarrow 1500 = \frac{1}{2}\times 10^3\left(v^2 - 1\right)$$

$$\Rightarrow v = 2\ \text{m/s}$$

By equation of continuity,
$A_1v_1 = A_2v_2$
$\Rightarrow 10^{-4} \times 1 = A_2 \times 2$
$\Rightarrow A_2 = 5 \times 10^{-5}$ m^2

38. (c) From equation of continuity: $A_1V_1 = A_2V_2$ Subscript 1 stands for piston and 2 for nozzle respectively.
We have: $d_1 = 20$ mm and $d_2 = 1$ mm
Therefore, $A_1 = \pi(20^2)$ and $A_1 = \pi(1^2)$
Also, $V_1 = 5$ m/s
Thus, $\pi(20^2) \times 5 = \pi(1^2) \times V_2$
$V_2 = 2$ m/s

39. (a) From the principle of continuity,

$$\frac{1}{2}\rho_a V_a^2 = \frac{1}{2}\rho_l V_l^2$$

For given V_a

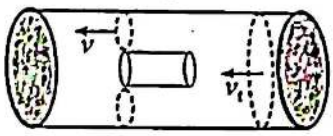
$$V_l \propto \sqrt{\frac{\rho_a}{\rho_l}}$$

40. (c) Let the,
Velocity of efflux $V = \sqrt{2g_{eff}l}$
where l is the length of the jar from top of point. time taken in covering horizontal distance is $T = \sqrt{\frac{2h}{g_{eff}}}$, where h is distance of floor from jar.
Horizontal range

$$= VT = \sqrt{2g_{eff}l}\sqrt{\frac{2h}{g_{eff}}} = \sqrt{4lh}$$

which is independent of g_{eff} So, d remains the same.
Except, In free-fall velocity of efflux will be zero, which means no water leaks out of the jar.

41. [9]



with respect to train

Applying Bernoulli's equation

$$P_0 + \frac{1}{2}\rho v_t^2 = P + \frac{1}{2}\rho v^2$$

$$P_0 - P = \frac{1}{2}\rho\left(v^2 - v_t^2\right) \quad \ldots(i)$$

From equation of continuity
Also, $4S_tv_t = v \times 3S_t$

$$\Rightarrow v = \frac{4}{3}v_t \quad \ldots(ii)$$

From (i) and (ii)

$$P_0 - P = \frac{1}{2}\rho\left(\frac{16}{9}v_t^2 - v_t^2\right) = \frac{1}{2}\rho\frac{7v_t^2}{9}$$

$\therefore\ \therefore N = 9$

42. [500] Let the pressure be P at the second point and let velocity be $v_2 = v$
Applying equation of continuity:
$A_1V_1 = A_2V_2$
$10 \times 1 = 5 \times v$
$\Rightarrow v = 2\ \text{ms}^{-1}$
Apply Bernoulli's theorem at both the points,

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho gh = P_2 + \frac{1}{2}\rho v_2^2 + \rho gh$$

[h = constant]

$$\Rightarrow 2000 + \frac{1}{2}\times 1000 \times 1^2 = P + \frac{1}{2}\times 1000 \times 4$$

$\therefore\ P = 500\ \text{P}_a$

43. (a) As the water falls downward, its velocity increases; therefore, its area will decrease. According to the equation of continuity, i.e., $Q = av = a$ constant.

44. [2] From equation of continuity,
$A_1v_1 = A_2v_2$

$$\Rightarrow \frac{A_1}{A_2}v_1 = \left(\frac{\pi r_1^2}{\pi r_2^2}\right)v_1$$

$$v_1\left(\frac{D}{d}\right)^2 v_1 = \left(\frac{8\times 10^{-3}}{2\times 10^{-3}}\right)^2 \times 0.25\,\text{m/s}$$

= 4 m /s (horizontal)
Vertical component of the velocity is zero.

@FAKE_CBSE_X @RAJ_EDUNET

Now, $H=\frac{1}{2}gt^2$

$\Rightarrow t=\sqrt{\frac{2H}{g}}$

Range is given by $R=v_2t=v_2$

$\sqrt{\frac{2H}{g}}=4\times\sqrt{\frac{2\times1.25}{10}}=2\text{m}$

45. From the equation of continuity at P and Q, we have

$a_1v_1=a_2v_2$

$\therefore v_2=\frac{a_1}{a_2}\times v_1=\frac{4\times10^{-3}}{8\times10^{-3}}\times1=\frac{1}{2}\text{ms}^{-1}$

From Bernoulli's theorem at points P and Q,

$p_1+\frac{1}{2}\rho v_1^2+\rho gh_1=p_2+\frac{1}{2}\rho v_2^2+\rho gh_2$

Each term in the above equation represents energy per unit volume.

Work done by the pressure per unit volume is:

$p_1-p_2=\frac{1}{2}\rho\left(v_2^2-v_1^2\right)+\rho g\left(h_2-h_1\right)$

$=\frac{1}{2}\times1000\left(0.5^2-1^2\right)+1000\times10\left(5-2\right)$

$=\frac{1}{2}\times1000\times\left(-0.75\right)+1000\times10\times3$

$=-0.375\times10^3+30\times10^3$

$=29.635\times10^3\text{ Jm}^{-3}$

Work done by gravity:

$W=\rho gh_1-\rho gh_2=-1000\times10\times(5-2)$

$=-3\times10^4\text{ Jm}^{-3}$

46. (*a*) Mass of the liquid inside container at $t=0$ is given by

$m_0=$ density $\times$ Volume $=\rho\times hA=\rho hA$

Lets say container starts moving with acceleration a_0, then force acting on container

$F=m_0a_0=\rho hAa_0$ ...(*i*)

Volume of the liquid flowing out of the hole per second

$=\frac{dV}{dt}=vA_h=\sqrt{2gh}\times\frac{A}{100}$ ...(*ii*)

Mass of the liquid flowing out of the hole per second

$=\frac{dm}{dt}=\rho\frac{dV}{dt}=\rho\times\sqrt{2gh}\times\frac{A}{100}$

Rate of momentum transferred to the container i.e. force acting on container

$F=\frac{dp}{dt}=v\frac{dm}{dt}$

$=\rho\times\left(2gh\right)\times\frac{A}{100}=0.02\rho ghA$

Equating (*i*) and (*ii*), we have

$\rho hAa_0=0.02\rho ghA$

$\Rightarrow a_0=0.02g=0.2=\frac{2}{10}\text{m/s}^2$

(*b*) The height of the liquid, when 75% of the liquid is drained out is, $H'=H/4$ and the velocity of efflux at that instant is

$v'=\sqrt{2gH'}=\sqrt{gH/2}$

$=\sqrt{m_0g/(2\rho A)}$

47. (*a, c, d*) Viscous force is given by

$F=-\eta A\frac{dv}{dy}$ since h is very small, so magnitude of viscous force is given by

$F=\eta A\frac{\Delta v}{\Delta y}$

$\therefore F=\frac{\eta Au_0}{h}$

(Because $v=u_0$ and $y=$ height of flud (h))

$\Rightarrow F\propto\eta, F\propto u_0;$

$F\propto\frac{1}{h}, F\propto A$

Since the plate is moving with constant velocity, the same force must be acting on the floor.

48. (*a,d*) For the body to float

$(\rho_1+\rho_2)V=(\sigma_1+\sigma_2)V$

$\rho_1+\rho_2=\sigma_1+\sigma_2$

As the strings are taut

$\rho_1<\sigma_1$ and $\rho_2>\sigma_2$

Now using Stokes law

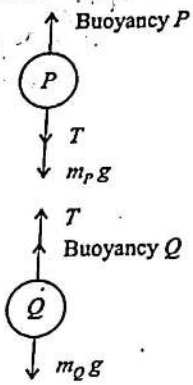
$V_P=\frac{2}{9}\frac{(\sigma_2-\rho_1)r^2g}{\eta_2}$

or $V_Q=\frac{2}{9}\frac{(\sigma_1-\rho_2)r^2g}{\eta_1}$

and as $\sigma_2-\rho_1=-(\sigma_1-\rho_2)$

$\left|\frac{V_P}{V_Q}\right|=\frac{\eta_1}{\eta_2}$

The dot product $V_P\cdot V_Q<0$ as V_P and V_Q are opposite.



49. [3] As per question,

Terminal velocity $v=\frac{2gr^2(\rho-\sigma)}{9\eta}$

$\Rightarrow\frac{v_p}{v_Q}=\frac{r_p^2\left(\rho_p-\sigma_1\right)\eta_2}{r_Q^2\left(\rho_Q-\sigma_2\right)\eta_1}$

Given: $\eta_1=3P\text{I}=30P$; $\eta_2=2P\text{I}=20P$; $\rho_P=\rho_Q=8\text{g cm}^{-3}$; $\sigma_1=0.8\text{g cm}^{-3}$ $\sigma_2=1.6\text{g cm}^{-3}$

Radius of sphere

$P=r_p=\frac{1}{2}\text{cm}=0.005\text{m}$

Radius of sphere

$Q=r_Q=\frac{0.5}{2}\text{cm}=0.0025\text{m}$

$\therefore\frac{V_p}{v_Q}=\frac{(0.005)^2(8-0.8)(20)}{(0.0025)^2(8-1.6)(30)}=3$

50. [1/720] This is also the excess pressure ΔP. By Poiscuille's equation, the rate of flow of liquid in the capillary tube

$Q=\frac{\pi(\Delta P)a^4}{8\eta l}$

$\therefore8\times10^{-6}=\frac{\left(\pi a^2\right)(\Delta P)}{8\eta}\left(\frac{a^2}{l}\right)$

$\therefore\eta=\frac{\left(\pi a^2\right)(\Delta P)\left(\frac{a^2}{l}\right)}{8\times8\times10^{-6}}$

Substituting the values, we have

$\eta=\frac{\left(10^{-6}\right)\left(\frac{4}{5}\times10^5\right)\left(2\times10^{-6}\right)}{8\times8\times10^{-6}}$

$=\frac{1}{720}\text{N}-\text{s/m}^2$

51. Terminal velocity $v_T=\frac{2r^2g}{9\eta}(\rho_s-\rho_l)$

and viscous force $F=6\pi\eta rv_T$

Rate of production of heat (power) : as viscous force is the only dissipative force.

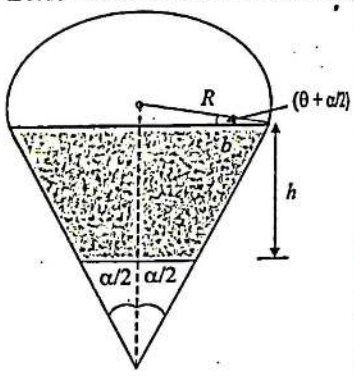
Hence, $\frac{dQ}{dt}=Fv_T=(6\pi\eta rv_T)(v_T)=6\pi\eta rv_T^2$

$=6\pi\eta r\left\{\frac{2}{9}\frac{r^2g}{\eta}(\rho_s-\rho_L)\right\}^2$

$=\frac{8\pi g^2}{27\eta}(\rho_s-\rho_L)^2r^5$ or $\frac{dQ}{dt}\propto r^5$

52. (*d*) As the bubble moves upwards, beside the buoyancy force (cause of which is pressure difference), the only force is gravity and force of viscosity will act.

53. (*d*) Let $R=$ radius of curvature of menisc



@FAKE CBSE X @RAJ_EDUCATION

$$b = R\cos\left(\theta+\frac{\alpha}{2}\right)$$

Excess pressure on concave side of meniscus

$$\frac{2S}{R} \Rightarrow (P_0+h\rho g)-P_0=\frac{2S}{R}$$

$$h\rho g=\frac{2S\cos\left(\theta+\frac{\alpha}{2}\right)}{b}$$

or $$h=\frac{2S}{b\rho g}\cos\left(\theta+\frac{\alpha}{2}\right)$$

54. (b) Pressure at a depth x from the surface of the water $= \rho gx$.

Hence net force on each surface of $ABCD$ is

$$\int_0^h (P_0+\rho gx)(2R\,dx) = 2P_0Rh + R\rho g h^2$$

However, the side attracts the segment due to surface tension acting along AB $= T(2R)$.

So, the net force acting on each side $= 2P_0Rh + Rpgh^2 - 2RT$

55. (b) $\Delta p_1 = \frac{4T}{r_1}$ and $\Delta p_2 = \frac{4T}{r_2}$

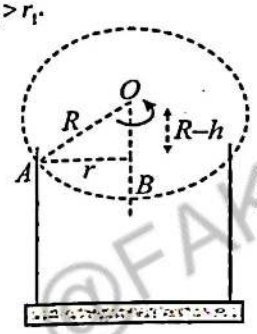
$r_1 < r_2 = \Delta p_1 > \Delta p_2$

$\therefore$ Air will flow from 1 to 2 and volume of bubble at end 1 will decrease.

Therefore, correct option is (b).

NOTE: Sub-hemispherical means $r_2 > r_1$.

56. (a,d)



In ΔOAB

$R^2 = (R-h)^2 + r^2$

$R^2 = R^2 - 2hR + h^2 + r^2$

$\Rightarrow 2hR = h^2 + r^2$

$$\Rightarrow R = \frac{h^2+r^2}{2h}$$

Now considering equation of surface

$$y = y_0 + \frac{\omega^2 r^2}{2g}$$

$$h = \frac{\omega^2 r^2}{2g}$$

Now using: $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2-\mu_1}{R}$

$$\Rightarrow \frac{1}{v} + \frac{4}{3(H-h)} = \frac{1-4/3}{-R}$$

$$\Rightarrow \frac{1}{v} = \frac{1}{3R} - \frac{4}{3H}$$

$$\Rightarrow \frac{1}{v} = \frac{2h}{3r^2} - \frac{4}{3H}$$

$$\Rightarrow \frac{1}{v} = -\frac{4}{3H}\left[1-\frac{\omega^2 H}{4g}\right]$$

$$\Rightarrow v = \frac{3H}{4}\left[1+\frac{\omega^2 H}{4g}\right]^{-1}$$

57. (a,b,c) $n_1 >> (n_1 - n_2) = \Delta n$

$$p_1 = \frac{n_1 RT}{N_A} \quad p_2 = \frac{n_2 RT}{N_A}$$

$$F = (n_1-n_2)k_B TS = \Delta n k_B TS \quad ...(a)$$

$$V = \frac{\Delta n k_B TS}{\beta}$$

Force balance $\Rightarrow$ Pressure $\times$ Area = Total number of molecules $\times \beta v$

$$\Delta n k_B TS = \Delta n_1 S\beta v$$

$$\Rightarrow n_1 \beta v \ell = \Delta n k_B T \quad ...(b)$$

Total number of molecules/sec

$$= \frac{(n_1 v\,dt)S}{dt}$$

$$= n_1 vS = \frac{\Delta n k_B TvS}{\beta v\ell}$$

$$= \left(\frac{\Delta n}{\ell}\right)\left(\frac{k_B T}{\beta}\right)S \quad ...(c)$$

As Δn will decrease with time therefore rate of molecules getting transfer decreases with time.

58. (a,c,d)

$$h = \frac{2T\cos\theta}{\rho gR};\ h_1 = \frac{2\times 0.075\times\cos 0^\circ}{1000\times 10\times 0.2\times 10^{-3}}$$

$\Rightarrow h_1 = 75$ mm (in T_1)

[If we assume entire tube of T_1]

$$\Rightarrow h_2 = \frac{2\times 0.075\times\cos 60^\circ}{1000\times 10\times 0.2\times 10^{-3}}$$

$= 37.5$ mm (in T_2)

[If we assume entire tube of T_2]

Option (a): Since contact angles are different so correction in the height of water column raised in the tube will be different in both the cases, so option (a) is correct

Option (b): If joint is 5 cm is above water surface, then lets say water crosses the joint by height h, then:

$$\Rightarrow P_0 - \frac{2T}{r} + \rho gh + \rho g\times 5\times 10^{-2} = P_0$$

$$\Rightarrow \cos\theta = \frac{R}{r},\ r = \frac{R}{\cos\theta}$$

$$\Rightarrow \rho g(h+5\times 10^{-2}) = \frac{2T\cos\theta}{R}$$

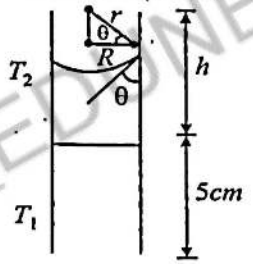
$$\Rightarrow h = \frac{2\times 0.075\times\cos 60}{0.2\times 10^{-3}\times 1000\times 10} - 5\times 10^{-2}$$

$\Rightarrow h = -ve$, not possible, so liquid will not cross the interface, but angle of contact at the interface will change, to balance the pressure,

So option (b) is wrong.

Option (c): If interface is 8 cm above water then water will not even reach the interface, and water will rise till 7.5 cm only in T_1, so option (c) is right.

Option (d): If interface is 5 cm above the water in vessel, then water in capillary will not even reach the interface. Water will reach only till 3.75 cm, so option (d) is right.



59. (a,c) $\frac{2\sigma}{R} = \rho gh$ [$R \rightarrow$ Radius of meniscus]

$$h = \frac{2\sigma}{Rpg}R = \frac{r}{\cos\theta}$$

[$r \rightarrow$ radius of capillary; $\theta \rightarrow$ contact angle]

$$h = \frac{2\sigma\cos\theta}{r\rho g}$$

(A) For given material, $\theta \rightarrow$ constant

$$h \propto \frac{1}{r}$$

(B) h depends on σ

(C) If lift is going up with constant acceleration,

$g_{eff} = (g+a)$

$$h = \frac{2\sigma\cos\theta}{r\rho(g+a)}$$

which means h decreases

(D) h is proportional to $\cos\theta$, NOT θ.

60. (a, b, d) For sphere A to be at the top in liquid, a density of sphere A should be less than a density of liquid. And for sphere B to be at the bottom in liquid, a density of sphere B should be greater than the density of a liquid.

The FBD of the top sphere gives us

$Vd_F g = T + Vd_A g$

and of the bottom sphere gives us

$T + Vd_F g = Vd_B g$

@FAKE_CBSE_K @RAJ_EDUNET

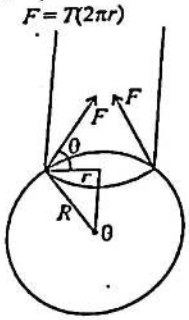
Substituting T from the first equation in the second we get

$2Vd_f g = Vd_A g + Vd_B g$

or $2d_f = d_A + d_B$

61. (c) $F_y = F\sin\theta$

$F = T(2\pi r)$



which is given by the tension and the circumference of the spherical drop.

$F_y = T(2\pi r)\sin\theta$

Putting the value of $\sin\theta$

$$F_{y'} = T(2\pi r)\frac{r}{R}$$

Hence,

$$\therefore\ F_{y'} = 2\pi T\frac{r^2}{R}$$

62. (a) Just before detaching force due to surface tension = weight of the liquid in the drop

$$T(2\pi r^2)/R = \left(\frac{4}{3}\pi R^3\right)\rho g$$

substituting the values we get

$R = 1.4 \times 10^{-3}$ m

63. (b) We know that,

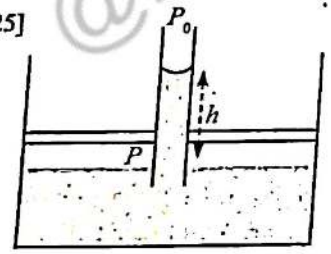
$$T = \frac{U}{a}$$

$$\therefore\ U = T \times a = T \times 4\pi R^2$$

$$= 0.11 \times 4 \times \frac{22}{7} \times (1.42\times10^{-3})^2$$

$= 2.7 \times 10^{-6}$ J

64. [25]



$$h_0 = \frac{2T\cos\theta}{\rho g r} = \frac{2\times0.075\times1}{10^3\times10\times10^{-4}}$$

$= 15$ cm

As the process is isothermal: $P_0V_0 = PV$

$$P_0V_0 = P\frac{100V_0}{101} \Rightarrow P = \frac{101}{100}P_0$$

Using pressure equation.

$$P_0 - \frac{2T\cos0}{r} + \rho g h = P = \frac{101}{100}P_0$$

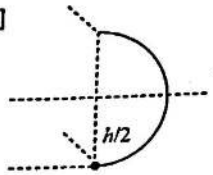
$$\Rightarrow -\rho g h_0 + \rho g h = \frac{P_0}{100}$$

$$\Rightarrow h = h_0 + \frac{P_0}{100\rho g}$$

$$\Rightarrow h = 15 + \frac{10^5}{100\times10^3\times10}$$

$= 15 + 10 = 25$ cm

65. [3.74]



Pressure at the bottom of disc = pressure due to surface tension

$$\rho g h = T\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$R_1 >>> R_2$

So $\frac{1}{R_1} <<< \frac{1}{R_2}$ and $R_2 = h/2$

$$\therefore\ \rho g h = T\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = T\left(0 + \frac{1}{h/2}\right)$$

$$h^2 = \frac{2T}{\rho g}$$

$$h = \sqrt{\frac{2T}{\rho g}} = \sqrt{\frac{2\times0.07}{10^3\times10}} = \sqrt{\frac{14\times100}{10^4\times100}}$$

$h = \sqrt{14}mm = 3.741$

66. [6] Using $V = \frac{4}{3}\pi R^3 = K\frac{4}{3}\pi r^3, R = 10^{-2}$

$$r = R\times k^{\frac{-1}{3}}$$

$$dA = (k\times4\pi r^2) - 4\pi R^2$$

$$dA = 4\pi R^2\left[k^{\frac{1}{3}} - 1\right]$$

$$\Delta U = T\times dA$$

$$10^{-3} = \frac{0.1}{4\pi}\times4\pi R^2\left[k^{\frac{1}{3}} - 1\right]$$

$$10^2 = \left[k^{\frac{1}{3}} - 1\right]$$

$k \approx 10^6$

$\alpha = 6$

67. [6] Let us consider P_A and P_B be the pressure present inside the soap bubbles A and B respectively. As excess pressure for soap bubble, $P = 4T/R$, where T surface tension.

So, the ideal gas equation for the two soap bubbles will be

$$P_A = P_0 + \frac{4T}{R_A}$$

$$P_B = P_0 + \frac{4T}{R_B}$$

On putting the values, we get

$$P_A = P_0 + \frac{4T}{R_A} = 8 + \frac{4(0.04)}{0.02} = 16\ \text{N/m}^2$$

and

$$P_B = P_0 + \frac{4T}{R_B} = 8 + \frac{4(0.04)}{0.04} = 12\ \text{N/m}^2$$

As $PV = nRt$, n is $\propto PV$

Thus,

$$\frac{n_A}{n_B} = \frac{P_AV_A}{P_BV_B} = \frac{16\times(4/3)\pi(0.02)^3}{12\times(4/3)\pi(0.04)^3} = \frac{1}{6}$$

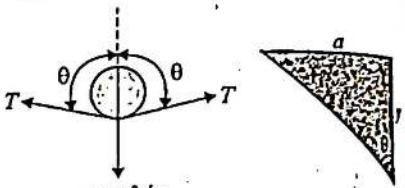
68. Find the required surface tension. Thinking about the balance of wire in vertical bearing

We have, $2T\,l\cos\theta = \lambda lg$

For, $y << a$, $\cos\theta = y/a$ putting the qualities in the above expression, we get

$T = \lambda a/2y$

The free-body outline of the wire is demonstrated in the figure.



$w = \lambda g$

T = surface tension

69. As Pressure due to moving air = ρv^2

Excess pressure inside the bubble = $4T/r$

The bubble will separate from the tube whey

$\rho v^2 = 4T/r$

$$r = \frac{4T}{\rho V^2}$$

@FAKE_CBSE_X_@RAJ_EDUNET

13 Kinetic Theory of Gases

Scan for Sol.

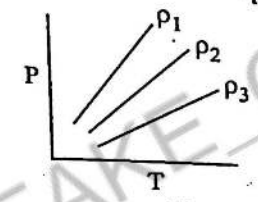
JEE-Main

Ideal Gas Laws

1. The temperature of a gas having 2.0×10^{25} molecules per cubic meter at 1.38 atm (Given, $k = 1.38 \times 10^{-23}$ JK^{-1}) is:
[29 Jan, 2024 (Shift-II)]
(a) 500 K (b) 200 K (c) 100 K (d) 300 K

2. Two vessels A and B are of the same size and are at same temperature. A contains 1g of hydrogen and B contains 1g of oxygen. PA and PB are the pressures of the gases in A and B respectively, then $\frac{P_A}{P_B}$ is:
[29 Jan, 2024 (Shift-I)]
(a) 16 (b) 8 (c) 4 (d) 32

3. P-T diagram of an ideal gas having three different densities ρ_1, ρ_2, ρ_3 (in three different cases) is shown in the figure. Which of the following is correct:
[04 April, 2024 (Shift-I)]



(a) $\rho_2 < \rho_3$ (b) $\rho_1 > \rho_2$
(c) $\rho_1 < \rho_2$ (d) $\rho_1 = \rho_2 = \rho_3$

4. The pressure (P) and temperature (T) relationship of an ideal gas obeys the equation $PT^2 =$ constant. The volume expansion coefficient of the gas will be:
[30 Jan, 2023 (Shift-I)]
(a) $3T$ (b) $\frac{3}{T^2}$ (c) $\frac{3}{T^3}$ (d) $\frac{3}{T}$

5. A vessel contains 16 g of hydrogen and 128 g of oxygen at standard temperature and pressure. The volume of the vessel in cm^3 is:
[29 June, 2022 (Shift-II)]
(a) 72×10^5 (b) 32×10^5 (c) 27×10^4 (d) 54×10^4

6. When a gas filled in a closed vessel is heated by raising the temperature by 1°C, its pressure increase by 0.4%. The initial temperature of the gas is _____K. [25 June, 2022 (Shift-II)]

7. A mixture of hydrogen and oxygen has volume 2000 cm^3, temperature 300 K, pressure 100 KPa and mass 0.76 g The ratio of number of moles of hydrogen to number of moles of oxygen in the mixture will be:
[27 June, 2022 (Shift-I)]
(a) $\frac{1}{3}$ (b) $\frac{3}{1}$ (c) $\frac{1}{16}$ (d) $\frac{16}{1}$

8. A balloon carries a total load of 185kg at normal pressure and temperature of 27°C. What load with the balloon carry on rising to a height at which the barometer pressure is 45 cm of Hg and the temperature.
[27 Aug, 2021 (Shift-I)]
(a) 279.07 kg (b) 214.15 kg (c) 181.46 kg (d) 123.54 kg

9. The volume V of an enclosure contains a mixture of three gases, 16 g of oxygen, 28 g of nitrogen and 44 g of carbon dioxide at absolute temperature T. Consider R as universal gas constant. The pressure of the mixture of gases is:
[16 March, 2021 (Shift-I)]
(a) $\frac{3RT}{V}$ (b) $\frac{5}{2}\frac{RT}{V}$ (c) $\frac{88RT}{V}$ (d) $\frac{4RT}{V}$

10. A container is divided into two chambers by a partition. The volume of first chamber is 4.5 litre and second chamber is 5.5 litre. The first chamber contain 3.0 moles of gas at pressure 2.0 atm and second chamber contain 4.0 moles of gas at pressure 3.0 atm. After the partition is removed and the mixture attains equilibrium, then, the common equilibrium pressure existing in the mixture is $x \times 10^{-1}$. Value of x is
[26 Feb, 2021 (Shift-I)]

11. For an ideal gas the instantaneous change in pressure p with volume V is given by the equation $\frac{dP}{dV} = -aP$. If $P = P_0$ at $V = 0$ is the given boundary condition, then the maximum temperature one mole of gas can attain is:
(Here R is the gas constant)
[31 Aug, 2021 (Shift-I)]
(a) 0°C (b) $\frac{aP_0}{eR}$ (c) $\frac{P_0}{aeR}$ (d) infinity

12. The change in the magnitude of the volume of an ideal gas when a small additional pressure ΔP is applied at a constant temperature, is the same as the change when the temperature is reduced by a small quantity ΔT at constant pressure. The initial temperature and pressure of the gas were 300 K and 2 atm. respectively. If $|\Delta T| = C|\Delta P|$ then value of C in (K/atm) is __. [4 Sep, 2020 (Shift-II)]

13. Initially a gas of diatomic molecules is contained in a cylinder of volume V_1 at a pressure P_1 and temperature 250 K. Assuming that 25% of the molecules get dissociated causing a change in numbe

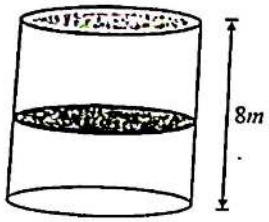
@FAKE_CBSE_KEY @TELEGRAM

of moles. The pressure of the resulting gas at temperature 2000 K, when contained in a volume $2V_1$ is given by P_2. The ratio $\frac{P_2}{P_1}$ is

[06 Sep, 2020 (Shift-I)]

14. A thermally isolated cylindrical closed vessel of height 8 m is kept vertically. It is divided into two equal parts by a diathermic (perfect thermal conductor) frictionless partition of mass 8.3 kg. Thus the partition is held initially at a distance of 4 m from the top, as shown in the schematic figure below. Each of the two parts of the vessel contains 0.1 mole of an ideal gas at temperature 300 K. The partition is now released and moves without any gas leaking from one part of the vessel to the other. When equilibrium is reached, the distance of the partition from the top (in m) will be _____.
(Take the acceleration due to gravity = 10 ms^{-2} and the universal gas constant = 8.3 J mol^{-1} K^{-1}).

[JEE Advance 2020]



15. A vertical closed cylinder is separated into two parts by a frictionless piston of mass m and of negligible thickness. The piston is free to move along the length of the cylinder. The length of the cylinder above the piston is l_1, and that below the piston is l_2, such that $l_1 > l_2$. Each part of the cylinder contains n moles of an ideal gas at equal temperature T. If the piston is stationary, its mass, m, will be given by:(R is universal gas constant and g is the acceleration due to gravity)

[12 Jan, 2019 (Shift-II)]

(a) $\frac{RT}{ng}\left[\frac{l_1-3l_2}{l_1 l_2}\right]$ (b) $\frac{RT}{g}\left[\frac{2l_1+l_2}{l_1 l_2}\right]$

(c) $\frac{nRT}{ng}\left[\frac{1}{l_2}+\frac{1}{l_1}\right]$ (d) $\frac{nRT}{g}\left[\frac{l_1-l_2}{l_{12}}\right]$

16. In a process, temperature and volume of one mole of an ideal monoatomic gas are varied according to the relation $VT = K$, where J is a constant. In this process the temperature of the gas is increased by ΔT. The amount of heat absorbed by gas is (R is gas constant)

[11 Jan, 2019 (Shift-II)]

(a) $\frac{1}{2}R\Delta T$ (b) $\frac{1}{2}KR\Delta T$ (c) $\frac{3}{2}R\Delta T$ (d) $\frac{2K}{3}\Delta T$

RMS, Average and Most Probable Speed

17. At which temperature the r.m.s. velocity of a hydrogen molecule equal to that of an oxygen molecule at 47°C?

[30 Jan, 2024 (Shift-I)]

(a) 80 K (b) −73 K (c) 4 K (d) 20 K

18. A sample contains mixture of helium and oxygen gas. The ratio of root mean square speed of helium and oxygen in the sample, is:

[06 April, 2024 (Shift-I)]

(a) $\frac{1}{32}$ (b) $\frac{2\sqrt{2}}{1}$ (c) $\frac{1}{4}$ (d) $\frac{1}{2\sqrt{2}}$

19. At temperature 300 K, the rms speed of oxygen molecules is $\sqrt{\frac{\alpha+3}{\alpha}}$ times to that of its average speed in the gas. Then, the value of α will be (use $\pi = \frac{22}{7}$)

[29 Jan, 2023 (Shift-I)]

(a) 32 (b) 28 (c) 24 (d) 27

20. If the root mean square velocity of hydrogen molecule at a given temperature and pressure is 2 Km/s, the root mean square velocity of oxygen at the same condition in Km/s is:

[1 Feb, 2024 (Shift-I)]

(a) 2.0 (b) 0.5 (c) 1.5 (d) 1.0

21. If the r.m.s. speed of chlorine molecule is 490 m/s at 27°C, the r.m.s speed of argon molecules at the same temperature will be (Atomic mass of argon = 39.9u, molecular mass of chlorine = 70.9u)

[12 Apr, 2023 (Shift-I)]

(a) 751.7 m/s (b) 451.7 m/s (c) 651.7 m/s (d) 551.7 m/s

22. The root mean square velocity of molecules of a gas is

[25 Jan, 2023 (Shift-I)]

(a) Proportional to square of temperature (T^2).

(b) Inversely proportional to square root of temperature $\sqrt{\frac{1}{T}}$

(c) Proportional to square root of temperature $\sqrt{T}$

(d) Proportional to temperature (T)

23. The rms speed of oxygen molecule in a vessel at particular temperature is $\left(1+\frac{5}{x}\right)^{\frac{1}{2}}$ v, where v is the average speed of the molecule. The value of x will be: (Take $\pi = \frac{22}{7}$)

[13 Apr, 2023 (Shift-I)]

(a) 28 (b) 27 (c) 8 (d) 4

24. The temperature of an ideal gas is increased from 200 K to 800 K. If r.m.s. speed of gas at 200 K is v_0. Then, r.m.s. speed of the gas at 800 K will be:

[6 Apr, 2023 (Shift-II)]

(a) v_0 (b) $4v_0$ (c) $\frac{v_0}{4}$ (d) $2v_0$

25. The root mean square speed of molecules of nitrogen gas at 27°C is approximately:
(Given mass of a nitrogen molecule −4.6 × 10^{-26} kg and take Boltzmann constant $k_B = 1.4 \times 10^{-23}$ JK^{-1})

[11 Apr, 2023 (Shift-II)]

(a) 523 m/s (b) 1260 m/s (c) 91 m/s (d) 27.4 m/s

26. Given below are two statements:

Statements I: The temperature of a gas is −73°C. When the gas is heated to 527°C, the root mean square speed of the molecules is doubled.

Statement II: The product of pressure and volume of an ideal gas will be equal to translational kinetic energy of the molecules.

In the light of the above statements, choose the correct answer from the options given below:

[24 Jan, 2023 (Shift-I)]

(a) Both statement I and Statement II are true
(b) Statement I is true but Statement II is false
(c) Both Statement I and Statement II are false
(d) Statement I is false but Statement II is true

@FAREDBE X @RADEBUNE

27. Three vessels of equal volume contain gases at the same temperature and pressure. The first vessel contains neon (monoatomic), the second contains chlorine (diatomic) and third contains uranium hexafloride (polyatomic). Arrange these on the basis of their root mean square speed (V_{rms}) and choose the correct answer from the options given below: **[11 Apr, 2023 (Shift-I)]**

(a) V_{rms} (mono) = V_{rms} (dia) = V_{rms} (poly)
(b) V_{rms} (mono) > V_{rms} (dia) > V_{rms} (poly)
(c) V_{rms} (dia) < V_{rms} (poly) < V_{rms} (mono)
(d) V_{rms} (mono) < V_{rms} (dia) < V_{rms} (poly)

28. The relation between root mean square speed (V_{rms}) and most probable speed (V_p) for the molar mass M of oxygen gas molecule at the temperature of 300K will be: **[25 June, 2022 (Shift-I)]**

(a) $v_{rms} = \sqrt{\frac{2}{3}} v_p$ (b) $v_{rms} = \sqrt{\frac{3}{2}} v_p$

(c) $V_{rms} = V_p$ (d) $v_{rms} = \sqrt{\frac{1}{3}} v_p$

29. What will be the effect on the root mean square velocity of oxygen molecules if the temperature is doubled and oxygen molecule dissociates into atomic oxygen? **[28 June, 2022 (Shift-II)]**

(a) The velocity of atomic oxygen remains same
(b) The velocity of atomic oxygen doubles
(c) The velocity of atomic oxygen becomes half
(d) The velocity of atomic oxygen becomes four times

30. Same gas is filled in two vessels of the same volume at the same temperature. If the ratio of the number of molecules is 1:4, then **[27 July, 2022 (Shift-I)]**

(A) The r.m.s. velocity of gas molecules in two vessels will be the same.
(B) The ratio of pressure in these vessels will be 1:4
(C) The ratio of pressure will be 1:1
(D) The r.m.s. velocity of gas molecules in two vessels will be in the ratio of 1:4

(a) A and C only (b) B and D only
(c) A and B only (d) C and D only

31. The root mean square speed of smoke particles of mass 5×10^{-17} kg in their Brownian motion in air at NTP is approximately. [Given $k = 138 \times 10^{-23}$ JK^{-1}] **[29 July, 2022 (Shift-II)]**

(a) 60 mm s^{-1} (b) 12 mm s^{-1} (c) 15 mm s^{-1} (d) 36 mm s^{-1}

32. 0.056 kg of Nitrogen is enclose in a vessel at a temperature of 127°C. The amount of heat required to double the speed of its molecules is _____ k cal.
(Take $R = 2$ cal $mole^{-1}$ K^{-1}) **[24 June, 2022 (Shift-I)]**

33. The rms speed of the molecules of Hydrogen, Oxygen and Carbondioxide at the same temperature are V_H, V_O and V_C respectively then: **[26 Aug, 2021 (Shift-I)]**

(a) $V_C > V_O > V_H$ (b) $V_H > V_O > V_C$
(c) $V_H = V_O = V_C$ (d) $V_H = V_O > V_C$

34. Consider a mixture of gas molecule of types A, B and C having masses $m_A < m_B < m_C$. The ratio of their root mean square speeds at normal temperature and pressure is: **[20 July, 2021 (Shift-I)]**

(a) $\frac{1}{v_A} > \frac{1}{v_B} > \frac{1}{v_C}$ (b) $v_A = v_B = v_C = 0$

(c) $\frac{1}{v_A} < \frac{1}{v_B} < \frac{1}{v_C}$ (d) $v_A = v_B \neq v_C$

35. Given below are two statements:
Statement I: In a diatomic molecule, the rotational energy at a given temperature obeys Maxwell's distribution.
Statement II: In a diatomic molecule, the rotational energy at a given temperature equals the translational kinetic energy for each molecule.
In the light of the above statements, choose the correct answer from the options given below: **[25 Feb, 2021 (Shift-II)]**

(a) Statement I is false but Statement II is true.
(b) Both Statement I and Statement II are true.
(c) Statement I is true but Statement II is false.
(d) Both Statement I and Statement II are false.

36. If the rms speed of oxygen molecules at 0°C is 160 m/s, find the rms speed of hydrogen molecules at 0°C. **[27 Aug, 2021 (Shift-II)]**

(a) 332 m/s (b) 640 m/s (c) 40 m/s (d) 80 m/s

37. Consider a sample of oxygen behaving like an ideal gas. At 300K, the ratio of root mean square (rms) velocity to the average velocity of gas molecule would be:
(Molecular weight of oxygen is 32 g/mol; $R = 8.3$ JK^{-1} mol^{-1}) **[18 March, 2021 (Shift-II)]**

(a) $\sqrt{\frac{8\pi}{3}}$ (b) $\sqrt{\frac{8}{3}}$ (c) $\sqrt{\frac{3}{3}}$ (d) $\sqrt{\frac{3\pi}{8}}$

38. The root mean square speed of molecules of a given mass of a gas at 27°C and 1 atmosphere pressure is 200 ms^{-1}. The root mean square speed of molecules of the gas at 127°C and 2 atmosphere pressure is $\frac{x}{\sqrt{3}}$ ms^{-1}. The value of x will be _____. **[24 Feb, 2021 (Shift-II)]**

39. A system consists of two types of gas molecules A and B having same number density $2 \times 10^{25}/m^3$. The diameter of A and B are 10Å and 5Å respectively. They suffer collision at room temperature. The ratio of average distance covered by the molecule A to that of B between two successive collision is _____ $\times 10^{-2}$. **[25 July, 2021 (Shift-II)]**

40. In a dilute gas at pressure P and temperature T, the mean time between successive collisions of a molecule varies with T as **[6 Sep, 2020 (Shift-II)]**

(a) $\sqrt{T}$ (b) T (c) $\frac{1}{\sqrt{T}}$ (d) $\frac{1}{T}$

41. Nitrogen gas is at 300°C temperature. The temperature (in K) at which the rms speed of a H_2 molecule would be equal to the rms speed of a nitrogen molecule, is _____.
(Molar mass of N_2 gas 28 g). **[05 Sep, 2020 (Shift-II)]**

42. A mixture of 2 moles of helium gas (atomic mass = 4 u), and 1 mole of argon gas (atomic mass = 40 u) is kept at 300 K in a container. The ratio of their rms speeds $\left[\frac{V_{rms}(\text{helium})}{V_{rms}(\text{argon})}\right]$, is close to: **[9 Jan, 2019 (Shift-I)]**

(a) 3.16 (b) 0.32 (c) 0.45 (d) 2.24

43. The area of a square is 5.29 cm^2. The area of 7 such squares taking into account the significant figures is **[9 April, 2019 (Shift-II)]**

(a) 37 cm^2 (b) 37.0 cm^2 (c) 37.03 cm^2 (d) 37.030 cm^2

@MKE_CBSE_K@RYLEDONET

44. For a given gas at 1 atm pressure, rms speed of the molecules is 200 m/s at 127°C. At 2 atm pressure and at 227°C, the rms speed of the molecules will be: **[9 April, 2019 (Shift-I)]**

(a) 80 m/s (b) $80\sqrt{5}$ m/s (c) 100 m/s (d) $100\sqrt{5}$ m/s

45. The number density of molecules of a gas depends on their distance r from the origin as, $n(r) = n_0 e^{-\alpha r^4}$. Then the total number of molecules is proportional to: **[12 April, 2019 (Shift-II)]**

(a) $n_0\alpha^{-3/4}$ (b) $n_0\alpha^{-3}$ (c) $n_0\alpha^{-1/4}$ (d) $\sqrt{n_0}a^{1/2}$

46. The temperature, at which the root mean square velocity of hydrogen molecules equals their escape velocity from the earth is closest to:
[Boltzmans Constant 23 $k_B = 1.38 \times 10^{-23}$ J / K
Avogadro number $N_A = 6.02 \times 10^{26}$ / kg
Radius of Earth: 6.4×10^6 m
Gravitation acceleration on Earth = 10 ms^{-2}]
[8 April, 2019 (Shift-II)]

(a) 800 k (b) 10^4 K (c) 3×10^5 (d) 650 K

47. A 15 g mass of nitrogen gas is enclosed in a vessel at a temperature 27°C. Amount of heat transferred to the gas, so that rms velocity of molecules is doubled, is about: [Take R = 8.3 J/K mole]
[9 Jan, 2019 (Shift-II)]

(a) 0.9 KJ (b) 6 KJ (c) 10 KJ (d) 14 KJ

Energy and Pressure of Gas

48. Given below are two statements:
Statement (I): The mean free path of gas molecules is inversely proportional to square of molecular diameter.
Statement (II): Average kinetic energy of gas molecules is directly proportional to absolute temperature of gas.
In the light of the above statements, choose the correct answer from the option given below: **[08 April, 2024 (Shift-II)]**

(a) Statement I is false but Statement II is true.
(b) Statement I is true but Statement II is false.
(c) Both Statement I and Statement II are false
(d) Both Statement I and Statement II are true.

49. A flask contains hydrogen and oxygen in the ratio of 2 : 1 by mass at temperature 27°C. The ratio of average kinetic energy per molecule of hydrogen and oxygen respectively is:
[30 Jan, 2023 (Shift-II)]

(a) 2 : 1 (b) 1 : 1 (c) 1 : 4 (d) 4 : 1

50. A flask contains Hydrogen and Argon in the ratio 2 : 1 by mass. The temperature of the mixture is 30°C. The ratio of average kinetic energy per molecule of the two gases (K argon/K hydrogen) is: (Given: Atomic Weight of Ar = 39.9) **[15 Apr, 2023 (Shift-I)]**

(a) 1 (b) 2 (c) $\frac{39.9}{2}$ (d) 39.9

51. The temperature at which the kinetic energy of oxygen molecules becomes double than its value at 27°C is
[8 Apr, 2023 (Shift-II)]

(a) 1227° C (b) 927°C (c) 327°C (d) 627° C

52. The average kinetic energy of a molecule of the gas is
[1 Feb, 2023 (Shift-I)]

(a) Proportional to absolute temperature
(b) Proportional to volume
(c) Proportional to pressure
(d) Dependent on the nature of the gas

53. According to kinetic theory of gases, **[27 June, 2022 (Shift-II)]**
(A) The motion of the gas molecules freezes at 0°C
(B) The mean free path of gas molecules decreases if the density of molecules is increased.
(C) The mean free path of gas molecules increases if temperature is increased keeping pressure constant.
(D) Average kinetic energy per molecule per degree of freedom is $\frac{3}{2}k_BT$ (for monoatomic gases)
Choose the most appropriate answer from the options given below.
[27 June, 2022 (Shift-II)]

(a) A and C only (b) B and C only
(c) A and B only (d) C and D only

54. Following statements are given: **[25 July, 2022 (Shift-I)]**
(A) The average kinetic energy of a gas molecule decreases when the temperature is reduced.
(B) The average kinetic energy of a gas molecule increases with increase in pressure at constant temperature.
(C) The average kinetic energy of a gas molecule decreases with increase in volume.
(D) Pressure of a gas increases with increase in temperature at constant pressure.
(E) The volume of gas decreases with increase in temperature.
Choose the correct answer from the options given below:

(a) (A) and (D) only (b) (A), (B) and (D) only
(c) (B) and (D) only (d) (A), (B) and (E) only

55. Given below are two statements:
Statement I: The average momentum of a molecule in a sample of an ideal gas depends on temperature.
Statement II: The rms speed of oxygen molecules in a gas is v. If the temperature is doubles and the oxygen molecules dissociate into oxygen atoms, the rms speeds will become $2v$. In the light of the above statements, choose the correct answer from the options given below: **[28 July, 2022 (Shift-I)]**

(a) Both Statement I and Statement II are true
(b) Both Statement I and Statement II are false
(c) Statements I is true but Statement II is false
(d) Statement I is false but Statement II is true

56. On the basis of kinetic theory of gases, the gas exerts pressure because its molecules: **[24 Feb, 2021 (Shift-II)]**

(a) Continuously lose their energy till it reaches wall.
(b) Suffer change in momentum when impinge on the walls of container.
(c) Are attracted by the walls of container.
(d) Continuously stick to the walls of container.

57. The number of molecules in one litre of an ideal gas at 300 K and 2 atmospheric pressure with mean kinetic energy 2×10^{-21} J per molecule is: **[27 July, 2021 (Shift-I)]**

(a) 0.75×10^{11} (b) 3×10^{11} (c) 6×10^{11} (d) 1.5×10^{11}

58. A mono-atomic gas of mass 4.0 u is kept in an insulated container. Container is moving with velocity 30 m/s. If container is suddenly stopped then change in temperature of the gas (R = gas constant) is $\frac{x}{3R}$. Value of x is **[25 Feb, 2021 (Shift-I)]**

© ONE CODE X @RAJ_SUNET

59. Number of molecules in a volume of 4 cm^3 of a perfect monoatomic gas at some temperature T and at a pressure of 2 cm of mercury is close to? (Given, mean kinetic energy of a molecule (at T) is 4×10^{-14} erg, $g = 980$ cm/s^2, density of mercury = 13.6 g/cm^3)
[5 Sep, 2020 (Shift-I)]
(a) 5.8×10^{18} (b) 4.0×10^{16} (c) 5.8×10^{16} (d) 4.0×10^{18}

60. A closed vessel contains 0.1 mole of a monatomic ideal gas at 200 K. If 0.05 mole of the same gas at 400 K is added to it, the final equilibrium temperature (in K) of the gas in the vessel will be close to _____.
[04 Sep, 2020 (Shift-I)]

61. An HCl molecule has rotational, translational and vibrational motions. If the rms velocity of HCl molecules in its gaseous phase is $\bar{v}$, m is its mass and k_B is Boltzmann constant, then its temperature will be:
[9 April, 2019 (Shift-I)]
(a) $\frac{m\bar{v}^2}{3k_B}$ (b) $\frac{m\bar{v}^2}{7k_B}$ (c) $\frac{m\bar{v}^2}{5k_B}$ (d) $\frac{m\bar{v}^2}{6k_B}$

Equipartion Theory, Degrees of Freedom, Specific Heat Capacity

62. The average kinetic energy of a monatomic molecule is 0.414 eV at temperature:
[27 Jan, 2024 (Shift-I)]
(Use $K_B = 1.38 \times 10^{-23}$ J/mol-K)
(a) 3000 K (b) 3200 K (c) 1600 K (d) 1500 K

63. The total kinetic energy of 1 mole of oxygen at 27° C is:
[Use universal gas constant (R) = 8.31 J/mole K]
[27 Jan, 2024 (Shift-II)]
(a) 6845.5 J (b) 5942.0 J (c) 6232.5 J (d) 5670.5 J

64. N moles of a polyatomic gas ($f = 6$) must be mixed with two moles of a monoatomic gas so that the mixture behaves as a diatomic gas. The value of N is:
[29 Jan, 2024 (Shift-II)]
(a) 6 (b) 3 (c) 4 (d) 2

65. The parameter that remains the same for molecules of all gases at a given temperature is:
[31 Jan, 2024 (Shift-I)]
(a) kinetic energy (b) momentum
(c) mass (d) speed

66. A gas mixture consists of 8 moles of argon and 6 moles of oxygen at temperature T. Neglecting all vibrational modes, the total internal energy of the system is
[31 Jan, 2024 (Shift-II)]
(a) 29 RT (b) 20 RT (c) 27 RT (d) 21 RT

67. Two moles a monoatomic gas is mixed with six moles of a diatomic gas. The molar specific heat of the mixture at constant volume is:
[1 Feb, 2024 (Shift-I)]
(a) $\frac{9}{4}R$ (b) $\frac{7}{4}R$ (c) $\frac{3}{2}R$ (d) $\frac{5}{2}R$

68. The translational degrees of freedom (f_t) and rotational degrees of freedom (f_r) of CH_4 molecule are:
[04 April, 2024 (Shift-II)]
(a) $f_t = 2$ and $f_r = 2$ (b) $f_t = 3$ and $f_r = 3$
(c) $f_t = 3$ and $f_r = 2$ (d) $f_t = 2$ and $f_r = 3$

69. Energy of 10 non rigid diatomic molecules at temperature T is:
[06 April, 2024 (Shift-II)]
(a) $\frac{7}{2}RT$ (b) $70\,K_BT$ (c) $35\,RT$ (d) $35\,K_BT$

70. A mixture of one mole of monoatomic gas and one mole of a diatomic gas (rigid) are kept at room temperature (27°C). The ratio of specific heat of gases at constant volume respectively is:
[08 April, 2024 (Shift-I)]
(a) 7/5 (b) 3/2 (c) 3/5 (d) 5/3

71. The temperature of a gas is –78°C and the average translational kinetic energy of its molecules is K. The temperature at which the average translational kinetic energy of the molecules of the same gas becomes 2K is:
[09 April, 2024 (Shift-II)]
(a) –39°C (2) 117°C (c) 127°C (4) –78°C

72. A closed container contains a homogeneous mixture of two moles of an ideal montomic gas ($\gamma = 5/3$) and one mole of an ideal diatomic gas ($\gamma = 7/5$). Here, γ is the ratio of the specific heats at constant pressure and constant volume of an ideal gas. The gas mixture does a work of 66 Joule when heated at constant pressure. The change in its internal energy is_____ Joule.
[JEE Advance 2023]

73. Let γ_1 be the ratio of molar specific heat at constant pressure and molar specific heat at constant volume of a monoatomic gas and γ_2 be the similar ratio of diatomic gas. Considering the diatomic gas molecule as a rigid rotator, the ratio, $\frac{\gamma_1}{\gamma_2}$ is
[24 Jan, 2023 (Shift-II)]
(a) $\frac{27}{35}$ (b) $\frac{35}{27}$ (c) $\frac{25}{21}$ (d) $\frac{21}{25}$

74. According to law of equipartition of energy the molar specific heat of a diatomic gas at constant volume where the molecule has one additional vibrational mode is:
[25 Jan, 2023 (Shift-II)]
(a) $\frac{9}{2}R$ (b) $\frac{5}{2}R$ (c) $\frac{3}{2}R$ (d) $\frac{7}{2}R$

75. A gas mixture consists of 2 moles of oxygen and 4 moles of neon at temperature T. Neglecting all vibrational modes, the total internal energy of the system will be:
[10 Apr, 2023 (Shift-II)]
(a) 8 RT (b) 16 RT (c) 4 RT (d) 11 RT

76. Heat energy of 735 J is given to a diatomic gas allowing the gas to expand at constant pressure. Each gas molecule rotates around an internal axis but do not oscillate. The increase in the internal energy of the gas will be:
[31 Jan, 2023 (Shift-II)]
(a) 525 J (b) 441 J (c) 572 J (d) 735 J

77. The correct relation between $\gamma = \frac{C_p}{c_v}$ and temperature T is:
[31 Jan, 2023 (Shift-I)]
(a) $\gamma \propto \frac{1}{\sqrt{T}}$ (b) $\gamma \propto T^0$ (c) $\gamma \propto \frac{1}{T}$ (d) $\gamma \propto T$

78. Match List-I with List-II:

List-I		List-II	
A.	3 Translational degrees of freedom	I.	Monoatomic gases
B.	3 Translational, 2 rotational degrees of freedoms	II.	Polyatomic gases
C.	3 Translational, 2 rotational and 1 vibrational degrees of freedom	III.	Rigid diatomic gases
D.	3 Translational, 3 rotational and more than one vibrational degrees of freedom	IV.	Nonrigid diatomic gases

@FAKE-CBSE-@JEEDUNET

Choose the correct answer from the options given below:

[10 Apr, 2023 (Shift-I)]

(a) A → IV; B → III; C → II; D → I
(b) A → IV; B → II; C → I; D → III
(c) A → I; B → III; C → IV; D → II
(d) A → I; B → IV; C → III; D → II

79. Sound travels in a mixture of two moles of helium and n moles of hydrogen. If rms speed of gas molecules in the mixture is $\sqrt{2}$ times the speed of sound, then the value of n will be:

[25 July, 2022 (Shift-II)]

(a) 1 (b) 2 (c) 3 (d) 4

80. A vessel contains 14 g of nitrogen gas at a temperature of 27°C. The amount of heat to be transferred to the gas to double the r.m.s speed of its molecules will be: Take $R = 8.32$ J mole^{-1} k^{-1}.

[28 July, 2022 (Shift-II)]

(a) 2229 J (b) 5616 J (c) 9360 J (d) 13,104 J

81. A small object is placed at the center of a large evacuated hollow spherical container. Assume that the container is maintained at 0 K. At time $T = 0$, the temperature of the object is 200 K. The temperature of the object becomes 100 K at $t = t_1$ and at 50 K. Assume the object and the container to be ideal black bodies. The heat capacity of the object does not depend on temperature. The ratio (t_2/t_1) is

[JEE Adv. 2021]

82. Consider two ideal diatomic gases A and B at some temperature T. Molecules of the gas A are rigid, and have a mass m. Molecules of the gas B have an additional vibrational mode and have mass $m/4$. The ratio of the specific heats (C_v^A and C_v^B) of gas A and B, respectively is:

[9 Jan, 2020 (Shift-I)]

(a) 3 : 5 (b) 5 : 7 (c) 7 : 9 (d) 5 : 9

83. Consider a mixture of n moles of helium gas and $2n$ moles of oxygen gas (molecules taken to be rigid) as an ideal gas. It C_p/C_v value will be:

[8 Jan, 2020 (Shift-II)]

(a) 19/13 (b) 40/27 (c) 67/45 (d) 23/15

84. Two moles of an ideal gas with $\frac{C_P}{C_V} = \frac{5}{3}$ are mixed with 3 moles of another ideal gas with $\frac{C_P}{C_V} = \frac{4}{3}$. The value of $\frac{C_P}{C_V}$ for the mixture is:

[7 Jan, 2020 (Shift-I)]

(a) 1.42 (b) 1.47 (c) 1.45 (d) 1.50

85. Match the C_p/C_v ratio for ideal gases with different type of molecules

[4 Sep, 2020 (Shift-I)]

Molecule Type		C_p/C_v	
A.	Monoatomic	I.	7/5
B.	Diatomic rigid molecules	II.	9/7
C.	Diatomic non-rigid molecules	III.	4/3
D.	Triatomic rigid molecules	IV.	5/3

(a) A → II, B → III, C → I, D → IV
(b) A → IV, B → II, C → I, D → III
(c) A → IV, B → I, C → II, D → III
(d) A → III, B → IV, C → II, D → I

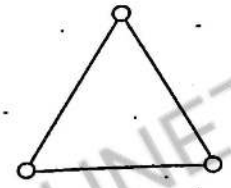
86. To raise the temperature of a certain mass of gas by 50°C at constant pressure, 160 calories of heat is required. When the same mass of gas is cooled by 100°C at constant volume, 240 calories of heat is released. How many degrees of freedom does each molecule of this gas have (assume gas to be ideal)? [3 Sep, 2020 (Shift-II)]

(a) 6 (b) 7 (c) 3 (d) 5

87. A gas mixture consists of 3 moles of oxygen and 5 moles of argon at temperature T. Assuming the gases to be ideal and the oxygen bond to be rigid, the total internal energy (in units of RT) of the mixture is [2 Sep, 2020 (Shift-I)]

(a) 13 (b) 15 (c) 20 (d) 11

88. Consider a gas of triatomic molecules. The molecules are assumed to be triangular and made of massless rigid rods whose vertices are occupied by atoms. The internal energy of a mole of the gas at temperature T is [3 Sep, 2020 (Shift-I)]



(a) $3RT$ (b) $\frac{9}{2}RT$ (c) $\frac{3}{2}RT$ (d) $\frac{5}{2}RT$

89. Molecules of an ideal gas are known to have three translational degrees of freedom and two rotational degrees of freedom. The gas is maintained at a temperature of T. The total internal energy, U, of a mole of this gas, and the value of $\gamma\left(\frac{C_p}{C_v}\right)$ are given, respectively, by [6 Sep, 2020 (Shift-I)]

(a) $U = 5RT$ and $\gamma = \frac{7}{5}$ (b) $U = \frac{5}{2}RT$ and $\gamma = \frac{6}{5}$

(c) $U = 5RT$ and $\gamma = \frac{6}{5}$ (d) $U = \frac{5}{2}RT$ and $\gamma = \frac{7}{5}$

90. An ideal gas occupies a volume of 2 m^3 at a pressure of 3×10^6 Pa. The energy of the gas is: [12 Jan, 2019 (Shift-I)]

(a) 9×10^6 J (b) 6×10^6 J
(c) 10^8 J (d) 3×10^2 J

91. An unknown metal of mass 192 g heated to a temperature of 100°C was immersed into a brass calorimeter of mass 128 g containing 240 g of water at a temperature of 8.4°C. Calculate the specific heat of the unknown metal if water temperature stabilizes at 21.5°C. (Specific heat of brass is 394 J kg^{-1} K^{-1}): [10 Jan, 2019 (Shift-II)]

(a) 458 J kg^{-1} K^{-1} (b) 1232 J kg^{-1} K^{-1}
(c) 916 J kg^{-1} K^{-1} (d) 654 J kg^{-1} K^{-1}

92. A gas mixture consists of 3 moles of oxygen and 5 moles of argon at temperature T. Considering only translational and rotational modes, the total internal energy of the system is: [11 Jan, 2019 (Shift-I)]

(a) 15 RT (b) 12 RT (c) 4 RT (d) 20 RT

93. A 15 g mass of nitrogen gas is enclosed in a vessel at a temperature 27°C. Amount of heat transferred to the gas, so that rms velocity of molecules is doubled, is about: [Take R = 8.3 J/K mole]

[9 Jan, 2019 (Shift-II)]

(a) 0.9 kJ (b) 6 kJ (c) 10 kJ (d) 14 kJ

@FAKE_CBSE_X @RAJ_EDUNET

Mean Free Path

94. If the collision frequency of hydrogen molecules in a closed chamber at 27°C is Z, then the collision frequency of the same system at 127°C is: [05 April, 2024 (Shift-I)]

(a) $\frac{\sqrt{3}}{2}Z$ (b) $\frac{4}{3}Z$

(c) $\frac{2}{\sqrt{3}}Z$ (d) $\frac{3}{4}Z$

95. If n is the number density and d is the diameter of the molecule, then the average distance covered by a molecule between two successive collisions (i.e. mean free path) is represented by: [05 April, 2024 (Shift-II)]

(a) $\frac{1}{\sqrt{2n\pi d^2}}$ (b) $\sqrt{2}n\pi d^2$

(c) $\frac{1}{\sqrt{2}n\pi d^2}$ (d) $\frac{1}{\sqrt{2}n^2\pi^2 d^2}$

96. The mean free path of molecules of a certain gas at STP is 1500d, where d is the diameter of the gas molecules. While maintaining the standard pressure, the mean free path of the molecules at 373K is approximately: [13 Apr, 2023 (Shift-II)]

(a) 1098 d (b) 2049 d (c) 750 d (d) 1500 d

97. The number of air molecules per cm^3 increased from 3×10^{19} to 12×10^{19}. The ratio of collision frequency of air molecules before and after the increase in number respectively is [06 Apr, 2023 (Shift-I)]

(a) 1.25 (b) 0.25 (c) 0.75 (d) 0.50

98. Calculate the value of mean free path (λ) for oxygen molecules at temperature 27°C and pressure 1.01×10^5 Pa. Assume the molecular diameter 0.3 nm and the gas is ideal.
($k = 1.38 \times 10^{-23}$ JK^{-1}) [16 March, 2021 (Shift-II)]

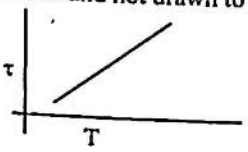
(a) 58 nm (b) 86 nm (c) 32 nm (d) 102 nm

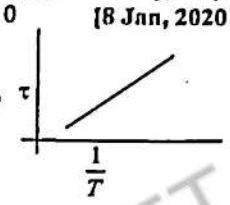
99. An ideal gas in a closed container is slowly heated. As its temperature increases, which of the following statements are true? [2 Sep, 2020 (Shift-II)]

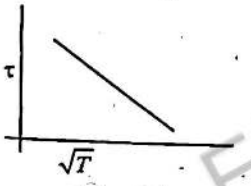
A. The mean free path of the molecules decreases.
B. The mean collision time between the molecules decreases.
C. The mean free path remains unchanged.
D. The mean collision time remains unchanged

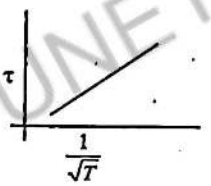
(a) C and D (b) A and D (c) B and C (d) A and B

100. The plot that depicts the behavior of the mean free time t (time between two successive collisions) for the molecules of an ideal gas, as a function of temperature (T), qualitatively, is: (Graphs are schematic and not drawn to scale) 0 [8 Jan, 2020 (Shift-I)]

(a) 

(b) 

(c) 

(d) 

101. Two gases argon (atomic radius 0.07 nm, atomic weight 40) and xenon (atomic radius 0.1 nm, atomic weight 140) have the same number density and are at the same temperature. The ratio of their respective mean free times is closest to: [9 Jan, 2020 (Shift-II)]

(a) 1.83 (b) 2.3 (c) 3.67 (d) 4.67

102. A 25×10^{-3} m^3 volume cylinder is filled with 1 mol of O_2 gas at room temperature (300 K). The molecular diameter of O_2, and its root mean square speed, are found to be 0.3 nm and 200 m/s, respectively. What is the average collision rate (per second) for an O_2 molecule? [10 April, 2019 (Shift-I)]

(a) $\sim 10^{10}$ (b) $\sim 10^{11}$ (c) $\sim 10^{12}$ (d) $\sim 10^{13}$

JEE-Advanced

RMS and KTG

Single Correct

1. Two non-reactive monoatomic ideal gases have their atomic masses in the ratio 2 : 3. The ratio of their partial pressures, when enclosed in a vessel kept at a constant temperature, is 4 : 3. The ratio of their densities is C-65.69, W-32.21, UA-2.11 (JEE Adv. 2013)

(a) 1:4 (b) 1:2 (c) 6:9 (d) 8:9

2. The temperature of an ideal gas is increased from 120 K to 480 K. If at 120 K the root mean square velocity of the gas molecules is v, at 480 K it becomes (IIT-JEE 1996)

(a) 4 v (b) 2 v (c) $v/2$ (d) $v/4$

3. The average translational kinetic energy of O_2 (molar mass 32) molecules at a particular temperature is 0.048 eV. The translational kinetic energy of N_2 (molar mass 28) molecules in eV at the same temperature is (IIT-JEE 1997)

(a) 0.0015 (b) 0.003 (c) 0.048 (d) 0.768

4. The average translational energy and the rms speed of molecules in a sample of oxygen gas at 300 K are 6.21×10^{-21} J and 484 m/s respectively. The corresponding values at 600 K are nearly (assuming ideal gas behaviour) (IIT-JEE 1997)

(a) 12.42×10^{-21} J,968 m/s (b) 8.78×10^{-21} J,684 m/s
(c) 6.21×10^{-21} J,968 m/s (d) 12.42×10^{-21} J,684 m/s

5. A vessel contains a mixture of one mole of oxygen and two moles of nitrogen at 300 K. The ratio of the average rotational kinetic energy per O_2 molecule to per N_2 molecule is (IIT-JEE 1998)

(a) 1 : 1 (b) 1 : 2 (c) 2 : 1
(d) depends on the moment of inertia of the two molecules

@FAKE_CBSE_X@_EDUNET

6. Three closed vessels A, B and C at the same temperature T and contain gases which obey the Maxwellian distribution of velocities. Vessel A contains only O_2, B only N_2 and C a mixture of equal quantities of O_2 and N_2. If the average speed of the O_2 molecules in vessel A is v_1, that of the N_2 molecules in vessel B is v_2, the average speed of the O_2 molecules in vessel C is (IIT-JEE 1992)

(a) $(v_1 + v_2)/2$ (b) v_1 (c) $(v_1 v_2)^{1/2}$ (d) $\sqrt{3kT/M}$

Multiple Correct

7. A container of fixed volume has a mixture of one mole of hydrogen and one mole of helium in equilibrium at temperature T. Assuming the gases are ideal, the correct statements is/are (JEE Adv. 2015)

(a) The average energy per mole of the gas mixture is $2RT$

(b) The ratio of speed of sound in the gas mixture to that in helium gas is $\sqrt{\frac{6}{5}}$

(c) The ratio of the rms speed of helium atoms to that of hydrogen molecules is $\frac{1}{2}$

(d) The ratio of the rms speed of helium atoms to that of hydrogen molecules is $\frac{1}{\sqrt{2}}$

8. Let $\bar{v}$, v_{ms} and v_p respectively denote the mean speed, root mean square speed and most probable speed of the molecules in an ideal monoatomic gas at absolute temperature T. The mass of a molecule is m. Then, (IIT-JEE 1998)

(a) no molecule can have a speed greater than $\sqrt{2}v_{rms}$

(b) no molecule can have speed less than $\frac{v_p}{\sqrt{2}}$

(c) $v_p < \bar{v} < v_{rms}$

(d) the average kinetic energy of a molecule is $\frac{3}{4}mv_p^2$

Subjective

9. A cubical box of side 1 m contains helium gas (atomic weight 4) at a pressure of 100 N/m^2. During an observation time of 1 s, an atom travelling with the root mean square speed parallel to one of the edges of the cube, was found to make 500 hits with a particular wall, without any collision with other atoms. Take, (IIT-JEE 2002)

$R = \frac{25}{3}$ J/mol-K and $k = 1.38 \times 10^{-23}$ J/K.

(a) Evaluate the temperature of the gas.
(b) Evaluate the average kinetic energy per atom.
(c) Evaluate the total mass of helium gas in the box.

10. One gram mole of oxygen at 27°C and one atmospheric pressure is enclosed in a vessel. (IIT-JEE 1983)

(a) Assuming the molecules to be moving with v_{rms}, find the number of collisions per second which the molecules make with one square meter area of the vessel wall.

(b) The vessel is next thermally insulated and moved with a constant speed v_0. It then suddenly stopped. The process results in a rise of the temperature of the gas by 1°C. Calculate the speed v_0.

True/False

11. The root mean square (rms) speed of oxygen molecules (O_2) at a certain temperature T (degree absolute) is V. If the temperature is doubled and oxygen gas dissociates into atomic oxygen, the rms speed remains unchanged. (IIT-JEE 1987)

12. The root mean square speeds of the molecules of different ideal gases, maintained at the same temperature are the same. (IIT-JEE 19

13. Two different gases at the same temperature have equal root mean square velocities. (IIT-JEE 19

Assertion and Reason

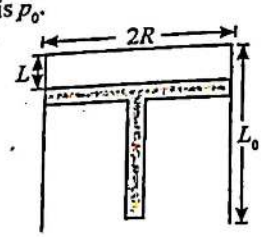
14. Assertion (A): The total translational kinetic energy of all the molecules of a given mass of an ideal gas is 1.5 times the product of its pressure and its volume.
Reason (R): The molecules of a gas collide with each other and the velocities of the molecules change due to the collision. (IIT-JEE 20

(a) Both A and R are correct and R is the correct explanation of A
(b) Both A and R are correct and R is not the correct explanation of A
(c) A is correct but R is not correct
(d) A is not correct but R is correct

Gas Law

Paragraph for Q.No. 72 to 74

A fixed thermally conducting cylinder has a radius R and height L_0. The cylinder is open at its bottom and has a small hole at its top. A piston of mass M is held at a distance L from the top surface, as shown in the figure. The atmospheric pressure is p_0.



15. The piston is now pulled out slowly and held at a distance $2L$ from the top. The pressure in the cylinder between its top and the piston will be

(a) p_0 (b) $\frac{p_0}{2}$ (c) $\frac{p_0}{2} + \frac{Mg}{\pi R^2}$ (d) $\frac{p_0}{2} - \frac{Mg}{\pi R^2}$

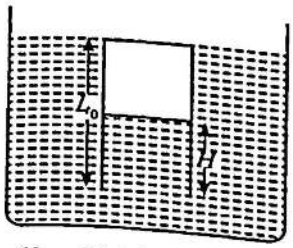
16. While the piston is at a distance $2L$ from the top, the hole at the top is sealed. The piston is then released to a position where it can stay in equilibrium. In this condition, the distance of the piston from the top is (IIT-JEE 20

(a) $\left(\frac{2p_0\pi R^2}{\pi R^2 p_0 + Mg}\right)(2L)$ (b) $\left(\frac{p_0\pi R^2 - Mg}{\pi R^2 p_0}\right)(2L)$

(c) $\left(\frac{p_0\pi R^2 + Mg}{\pi R^2 p_0}\right)(2L)$ (d) $\left(\frac{p_0\pi R^2}{\pi R^2 p_0 - Mg}\right)(2L)$

17. The piston is taken completely out of the cylinder. The hole at the top is sealed. A water tank is brought below the cylinder and put in a position so that the water surface in the tank is at the same level as the top of the cylinder as show in the figure. The density of the water is ρ. In equilibrium, the height H of the water column in the cylinder satisfies (IIT-JEE 20

@RAKESH SIR FREE X @RAKESH SIR FREE



(a) $\rho g(L_0 - H)^2 + p_0(L_0 - H) + L_0 p_0 = 0$
(b) $\rho g(L_0 - H)^2 - p_0(L_0 - H) - L_0 p_0 = 0$
(c) $\rho g(L_0 - H)^2 + p_0(L_0 - H) - L_0 p_0 = 0$
(d) $\rho g(L_0 - H)^2 - p_0(L_0 - H) + L_0 p_0 = 0$

18. A vessel contains 1 mole of O_2 gas (molar mass 32) at a temperature T. The pressure of the gas is p. An identical vessel containing one mole of the gas (molar mass 4) at a temperature $2T$ has a pressure of **(IIT-JEE 1997)**

(a) $p/8$ (b) p (c) $2p$ (d) $8p$

Multiple Correct

19. From the following statements concerning ideal gas at any given temperature T, select the correct one (s). **(IIT-JEE 1995)**

(a) The coefficient of volume expansion at constant pressure is the same for all ideal gases

(b) The average translational kinetic energy per molecule of oxygen gas is $3\,kT$, k being Boltzmann constant

(c) The mean-free path of molecules increases with decrease in the pressure

(d) In a gaseous mixture, the average translational kinetic energy of the molecules of each component is different

Numerical Types/Integer Types

20. A gas thermometer is used as a standard thermometer for measurement of temperature. When the gas container of the thermometer is immersed in water at its triple point 273.16K, the pressure in the gas thermometer reads 3.0×10^4 N/m². When the gas container of the same thermometer is immersed in another system, the gas pressure reads 3.5×10^4 N/m². The temperature of this system is therefore.....C. **(IIT-JEE 1997)**

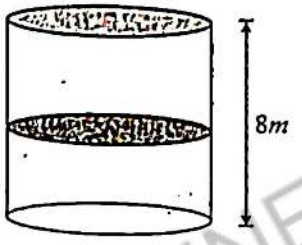
21. A closed container of volume 0.02m³ contains a mixture of neon and argon gases, at a temperature of 27°C and pressure of 1×10^5Nm^{-2}. The total mass of the mixture is 28g. If the molar masses of neon and argon are 20 and 40g mol^{-1} respectively, find the masses of the individual gases in the container assuming them to be ideal. (Universal gas constant = 8.314 J/mol – K). **(IIT-JEE 1994)**

22. A thin tube of uniform cross-section is sealed at both ends. It lies horizontally, the middle 5cm containing mercury and the two equal ends containing air at the same pressure p. When the tube is held at an angle of 60° with the vertical direction, the length of the air column above and below the mercury column are 46cm and 44.5cm respectively. Calculate the pressure p in centimeters of mercury. (The temperature of the system is kept at 30°C). **(IIT-JEE 1986)**

23. Two glass bulbs of equal volume are connected by a narrow tube and are filled with a gas at 0°C and a pressure of 76cm of mercury. One of the bulbs is then placed in melting ice and the other is placed in a water bath maintained at 62°C . What is the new value of the pressure inside the bulbs? The volume of the connecting tube is negligible. **(IIT-JEE 1985)**

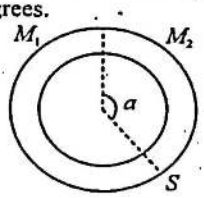
Fill in the Blanks

24. A thermally isolated cylindrical closed vessel of height 8 m is kept vertically. It is divided into two equal parts by a diathermic (perfect thermal conductor) frictionless partition of mass 8.3 kg. Thus the partition is held initially at a distance of 4 m from the top, as shown in the schematic figure below. Each of the two parts of the vessel contains 0.1 mole of an ideal gas at temperature 300 K. The partition is now released and moves without any gas leaking from one part of the vessel to the other. When equilibrium is reached, the distance of the partition from the top (in m) will be _____. (Take the acceleration due to gravity = 10 ms^{-2} and the universal gas constant = 8.3 J mol^{-1} K^{-1}). **(JEE Adv. 2020)**



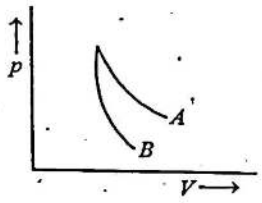
25. During an experiment, an ideal gas is found to obey an additional law p^2V = constant. The gas is initially at a temperature T and volume V. When it expands to a volume $2V$, the temperature becomes ..... **(IIT-JEE 1987)**

26. A ring shaped tube contains two ideal gases with equal masses and relative molar masses $M_1 = 32$ and $M_2 = 28$. The gases are separated by one fixed partition and another movable stopper S which can move freely without friction inside the ring. The angle as shown in the figure is..... degrees. **(IIT-JEE 1997)**



True/False

27. The curves A and B in the figure show p-V graphs for an isothermal and an adiabatic process for an ideal gas. The isothermal process is represented by the curve A. **(IIT-JEE 1985)**

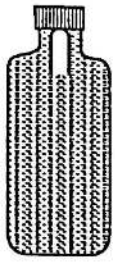


Comprehension Based/Passage Based

A soft plastic bottle, filled with water of density 1gm/cc, carries an inverted glass test-tube with some air (ideal gas) trapped as shown in the figure. The test-tube has a mass of 5gm, and it is made of a thick glass of density 2.5gm/cc.

Initially the bottle is sealed at atmospheric pressure $p_0 = 10^5$ Pa so that the volume of the trapped air is $v_0 = 3.3$cc. When the bottle is squeezed from outside at constant temperature, the pressure inside rises and the volume of the trapped air reduces. It is found that the test tube begins to sink at pressure $p_0 + \Delta p$ without changing its orientation. At this pressure, the volume of the trapped air is $v_0 - \Delta v$. Let $\Delta v = X$cc and $\Delta p = Y \times 10^3$ Pa.

CRACKJEE.X@GMAIL.NET



28. The value of X is ___ C5.14 W-62.38 UA-32.48 (JEE Adv. 2021)

29. The value of Y is ___ C3.29 W-63.79 UA-32.92 (JEE Adv. 2021)

Internal Energy, Specific Heat, Degrees of Freedom

Single Correct

30. An ideal gas is in thermodynamic equilibrium. The number of degrees of freedom of a molecule of the gas is n. The internal energy of one mole of the gas is U_n and the speed of sound in the gas is v_n. At a fixed temperature and pressure, which of the following is the correct option? C-29.36, W-30.17, UA-40.47 (JEE Adv. 2023)

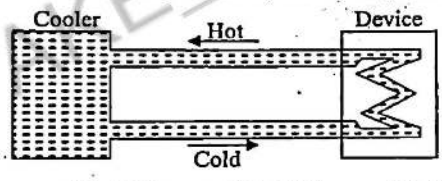
(a) $v_3 < v_6$ and $U_3 > U_6$

(b) $v_5 > v_3$ and $U_3 > U_5$

(c) $v_5 > v_7$ and $U_5 < U_7$

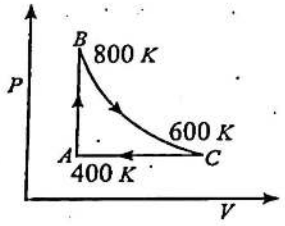
(d) $v_6 < v_7$ and $U_6 < U_7$

31. A water cooler of storage capacity 120 litres can cool water at a constant rate of P watts. In a closed circulation system (as shown schematically in the figure), the water from the cooler is used to cool an external device that generates constantly 3kW of heat (thermal load). The temperature of water fed into the device cannot exceed 30°C and the entire stored 120 litres of water is initially cooled to 10°C. The entire system is thermally insulated. The minimum value of P (in watts) for which the device can be operated for 3 hours is (Specific heat of water is 4.2 $kJ^{-1}K^{-1}$ and the density of water is 1000 $kg\ m^{-3}$) C-11.2, W-21.48, UA-67.32 (JEE Adv. 2016)



(a) 1600 (b) 2067 (c) 2533 (d) 3933

32. One mole of diatomic ideal gas undergoes a cyclic process ABC as shown in figure. The process BC is adiabatic. The temperatures at A, B and C are 400 K,800 K and 600 K respectively. Choose the correct statement: (JEE Adv. 2014)



(a) The change in internal energy in the process AB is -350R

(b) The change in internal energy in the process BC is -500R

(c) The change in internal energy in whole cyclic process is 250R

(d) The change in internal energy in the process CA is 700R

33. Water of volume 2L in a container is heated with a coil of 1kW at 27°C. The lid of the container is open and energy dissipates at a rate of 160J/s. In how much time temperature will rise from 27°C to 77°C? [Specific heat of water is 4.2 kJ/kg] (IIT-JEE 2008)

(a) 8 min 20 s (b) 6 min 2 s (c) 7 min (d) 14 min

34. 2 kg of ice at –20°C is mixed with 5 kg of water at 20°C in an insulating vessel having a negligible heat capacity. Calculate the final mass of water remaining in the container. It is given that the specific heats of water and ice are 1 kcal/kg/°C and 0.5 kcal/kg/°C while the latent heat of fusion of ice is 80 kcal/g. (IIT-JEE 2008)

(a) 7 kg (b) 6 kg (c) 4 kg (d) 2 kg

35. A gas mixture consists of 2 moles of oxygen and 4 moles of argon at temperature T. Neglecting all vibrational modes, the total internal energy of the system is (IIT-JEE 1998)

(a) 4 RT (b) 15 RT (c) 9 RT (d) 11 RT

36. Two cylinders A and B fitted with pistons contain equal amounts of an ideal diatomic gas at 300 K. The piston of A is free to move while that of B is held fixed. The same amount of heat is given to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K, then the rise in temperature of the gas in B is (IIT-JEE 1998)

(a) 30 K (b) 18 K (c) 50 K (d) 42 K

37. If one mole of a monoatomic gas ($\gamma = 5/3$) is mixed with one mole of a diatomic gas ($\gamma = 7/5$), the value of γ for the mixture is (IIT-JEE 1998)

(a) 1.40 (b) 1.50 (c) 1.53 (d) 3.07

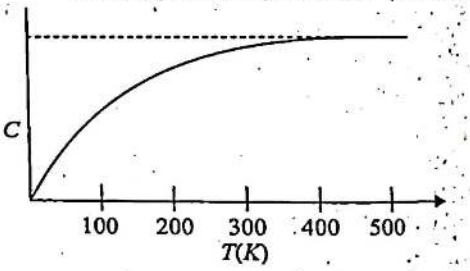
38. 70 cal of heat are required to raise the temperature of 2 moles of an ideal diatomic gas at constant pressure from 30°C to 35°C. The amount of heat required (in calorie) to raise the temperature of the same gas through the same range (30°C to 35°C) at constant volume is (IIT-JEE 1998)

(a) 30 (b) 50 (c) 70 (d) 90

Multiple Correct

39. The figure below shows the variation of specific heat capacity (C) of a solid as a function of temperature (T). The temperature is increased continuously from 0 to 500K at a constant rate. Ignoring any volume change, the following statement(s) is (are) correct in a reasonable approximation.

C-22.11, W-43.12, UA-34.77 (JEE Adv. 201



@FREE_PDF_ON_TELEGRAM

(a) The rate at which heat is absorbed in the range 0–200K varies linearly with temperature T

(b) Heat absorbed in increasing the temperature from 0–100K is less than the heat required for increasing the temperature from 400–500K

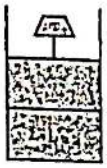
(c) There is no change in the rate of heat absorption in the range 400–500K

(d) The rate of heat absorption increases in the range 200–300K

Comprehension Based/Passage Based

40. In the figure a container is shown to have a movable (without friction) piston on top. The container and the piston are all made of perfectly insulating material allowing no heat transfer between outside and inside the container. The container is divided into two compartments by a rigid partition made of a thermally conducting material that allows slow transfer of heat.

The lower compartment of the container is filled with 2 moles of an ideal monoatomic gas at 700K and the upper compartment is filled with 2 moles of an ideal diatomic gas at 400K. The heat capacities per mole of an ideal monoatomic gas are $C_V = \frac{3}{2}R, C_p = \frac{5}{2}R$, and those for an ideal diatomic gas are $C_V = \frac{5}{2}R, C_p = \frac{7}{2}R$.



Consider the partition to be rigidly fixed so that it does not move. When equilibrium is achieved, the final temperature of the gases will be **C-4.88, W-47.62, UA-47.5 (JEE Adv. 2014)**

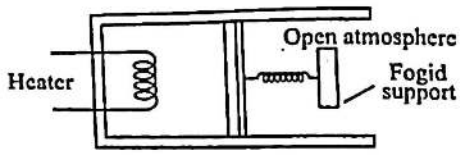
(a) 550K (b) 525K (c) 513K (d) 490K

Numerical Types/Integer Types

41. An ideal gas has a specific heat at constant pressure $C_p = \frac{5R}{2}$. The gas is kept in a closed vessel of volume 0.0083 m^3, at a temperature of 300K and a pressure of 1.6×10^6 N/m^2. An amount of 2.49×10^4 J of heat energy is supplied to the gas. Calculate the final temperature and pressure of the gas. **(IIT-JEE 1987)**

42. A 5m long cylindrical steel wire with radius 2×10^{-3}m is suspended vertically from a rigid support and carries a bob of mass 100kg at the other end. If the bob gets snapped, calculate the change in temperature of the wire ignoring losses. (For the steel wire : Young's modulus 5.1×10^{11} Pa. Density = 7860 kg/m^3; Specific heat = 420 J/kg – K) **(IIT-JEE 2001)**

43. An ideal mono atomic gas is confined in a cylinder by a spring-loaded piston of cross-section $8.0 \times 10^{-3} m^3$. Initially the gas is at 300K and occupies a volume of $2.4 \times 10^{-3} m^3$ and the spring is in its relaxed (unstretched, uncompressed) state. The gas is heated by a small electric heater until the piston moves out slowly by 0.1m.



Calculate the final temperature of the gas and the heat supplied (in joules) by the heater. The force constant of the spring is 8000 N/m, and the atmospheric pressure 1.0×10^5 Nm^{-2}. The cylinder and the piston are thermally insulated. The piston is massless and there is no friction between the piston and the cylinder. Neglect heat loss through the lead wires of the heater. The heat capacity of the heater coil is negligible. Assume the spring to be massless. **(IIT-JEE 1989)**

44. A lead bullet just melts when stopped by an obstacle. Assuming that 25 per cent of the heat is absorbed by the obstacle, find the velocity of the bullet if its initial temperature is 27°C. **(IIT-JEE 1981)**

Fill in the Blanks

45. A substance of mass M kg requires a power input of P watts to remain in the molten state at its melting point. When the power source is turned off, the sample completely solidifies in time t seconds. The latent heat of fusion of the substance is.... **(IIT-JEE 1992)**

46. 300g of water at 25°C is added to 100g of ice at 0°C. The final temperature of the mixture is ....°C. **(IIT-JEE 1989)**

47. One mole of a monoatomic ideal gas is mixed with one mole of a diatomic ideal gas. The molar specific heat of the mixture at constant volume is ..... . **(IIT-JEE 1984)**

48. A closed container contains a homogeneous mixture of two moles of an ideal monotonic gas ($\gamma = 5/3$) and one mole of an ideal diatomic gas ($\gamma = 7/5$). Here, γ is the ratio of the specific heats at constant pressure and constant volume of an ideal gas. The gas mixture does a work of 66 Joule when heated at constant pressure. The change in its internal energy is_____ Joule.

C-10.26 W-60.44 UA-29.3 [JEE Adv. 2023]

Subjective

49. An insulated box containing a monoatomic gas of molar mass M moving with a speed v_0 is suddenly stopped. Find the increment in gas temperature as a result of stopping the box. **(IIT-JEE 2003)**

50. A solid sphere of copper of radius R and a hollow sphere of the same material of inner radius r and outer radius R are heated to the same temperature and allowed to cool in the same environment. Which of them starts cooling faster? **(IIT-JEE 1982)**

Integer Type

51. A small object is placed at the center of a large evacuated hollow spherical container. Assume that the container is maintained at 0 K. At time $t = 0$, the temperature of the object is 200 K. The temperature of the object becomes 100 K at $t = t_1$ and 50 K at $t = t_2$. Assume the object and the container to be ideal black bodies. The heat capacity of the object does not depend on temperature. The ratio (t_2/t_1) is **C-2.71 W-80.51 UA-16.78 (JEE Adv. 2021)**

@FIKE_CBSE_X_GRADEJUNCT

ANSWER KEY

JEE-Main

1. (a)	2. (a)	3. (b)	4. (d)	5. (c)	6. [250]	7. (b)	8. (d)	9. (b)	10. [26]
11. (c)	12. [150]	13. [05.00]	14. [6]	15. (d)	16. (a)	17. (d)	18. (b)	19. (b)	20. (b)
21. (c)	22. (c)	23. (a)	24. (d)	25. (a)	26. (b)	27. (b)	28. (b)	29. (b)	30. (c)
31. (c)	32. [12]	33. (b)	34. (c)	35. (c)	36. (b)	37. (d)	38. [400]	39. [25]	40. (c)
41. [40.93]	42. (a)	43. (b)	44. (d)	45. (a)	46. (b)	47. (c)	48. (d)	49. (b)	50. (a)
51. (c)	52. (a)	53. (b)	54. (a)	55. (d)	56. (b)	57. (d)	58. [3600]	59. (d)	60. [266.67]
61. (a)	62. (b)	63. (c)	64. (c)	65. (a)	66. (c)	67. (a)	68. (b)	69. (d)	70. (c)
71. (b)	72. [121]	73. (c)	74. (d)	75. (d)	76. (a)	77. (b)	78. (c)	79. (b)	80. (c)
81. [9]	82. (b)	83. (a)	84. (a)	85. (c)	86. (a)	87. (b)	88. (a)	89. (d)	90. (*)
91. (c)	92. (a)	93. (c)	94. (c)	95. (c)	96. (b)	97. (b)	98. (d)	99. (c)	100. (d)
101. (a)	102. (a)								

JEE-Advanced

1. (d)	2. (b)	3. (c)	4. (d)	5. (a)	6. (b)	7. (a, b, d)	8. (c, d)	11. [False] 12. [False]
13. [False]	14. (b)	15. (a)	16. (d)	17. (c)	18. (c)	19. (a, c)	20. [45.53]	21. [4.0744, 23.926]
22. [75.4]	23. [83.75]	24. [6]	27. [True]	28. [0.30]	29. [10]	30. (c)	31. (b)	32. (b) 33. (a)
34. (b)	35. (d)	36. (d)	37. (b)	38. (b)	39. (b, c, d)	40. (d)	41. [675, 3.6×10^6]	
42. [4.54×10^{-3}]		43. [800, 720]		44. [410]	48. [121]	51. [9]		

EXPLANATIONS

JEE-Main

1. (a) By using ideal gas equation $PV = nRT$

$$PV = \frac{N}{N_A}RT$$

N – Total no. of molecules $P = \frac{N}{V}kT$

$1.38 \times 1.01 \times 10^5 = 2 \times 10^{25} \times 1.38 \times 10^{-23} \times T$

$$T = \frac{1.01\times10^3}{2} \approx 500\ \text{K}$$

2. (a) Using Ideal Gas Equation

$$\frac{P_A V_A}{P_B V_B} = \frac{n_A R T_A}{n_B R T_B}$$

Given $V_A = V_B$

and $T_A = T_B$

$$\frac{P_A}{P_B} = \frac{n_A}{n_B}$$

$$\frac{P_A}{P_B} = \frac{1/2}{1/32} = 16$$

3. (b) For ideal gas, $PV = nRT$

$$\therefore P\left(\frac{m}{V}\right)\frac{RT}{M} \Rightarrow P = \frac{\rho RT}{M}$$

(Where m is mass of gas and M is molecular mass of gas)

For same temperature $P_1 > P_2 > P_3$

So $\rho_1 > \rho_2 > \rho_3$

4. (d) PT = constant, Using $PV = nRT$

$$P = \frac{nRT}{V}$$

$$PT^2 = \frac{nRT}{V} \times T^2 = \text{constant}$$

$$\Rightarrow T^3 = KV$$

So, $\frac{d}{dT}(KV) = 3T^2$

$$\Rightarrow \frac{KdV}{dT} = 3T^2$$

$$\Rightarrow dV = \frac{3T^2}{K}dT$$

$$dV = V\gamma dT$$

$$\Rightarrow \gamma V = \frac{3T^2}{K} \Rightarrow \gamma = \frac{3T^2}{KV} = \frac{3T^2}{T^3} = \frac{3}{T}$$

5. (c) No of moles of $H_2 = 8$ moles

No of moles of $O_2 = 4$ moles

Total moles = 12 moles

At STP 1 mole occupy = $22.4\ \ell \times 10^3\ \text{cm}^3$

12 moles will occupy $12 \times 22.4 \times 10^3\ \text{cm}^3$

$\approx 26.8 \times 10^4\ \text{cm}^3$

6. [250] $PV = nRT$

$\Delta P.V. = nR\Delta T$

$$\frac{\Delta P}{P} = \frac{\Delta T}{T} = \frac{0.4}{100}$$

$$T = \frac{100\times1}{0.4} = 250\,K$$

7. (b) $PV = nRT$

$$n = \frac{100\times10^3 \times 2000\times10^{-6}}{\frac{25}{3}\times300}$$

$n = 80 \times 10^{-3}$

$n_1 + n_2 = 0.08$

$n_1 \times 2 + n_2 \times 32 = 0.76$

$(0.08 - n_2)2 + n_2(32) = 0.76$

$n_2 = 0.02$

$n_1 = 0.06$

$$\frac{n_1}{n_2} = \frac{3}{1}$$

8. (d) Let as suppose, Initial load $M_1 = 185$kg. Initial temperature, $T_1 = 27°C$ = 300K, Initial Pressure, P_1 = 76cm, Final Pressure $P_2 = 45$ cm.

@TAKE_CBSE_Y@RAJ_EDUNET

We have to calculate final load of ballon at 45 cm of Hg pressure.

$P = \rho RT$

$\Rightarrow \frac{\rho_1}{\rho_2} = \frac{P_1}{P_2} \times \frac{T_2}{T_1} = \frac{76}{45} \times \frac{260}{300}$

$\Rightarrow \frac{\rho_1}{\rho_2} = \frac{M_1}{M_2}$

$\Rightarrow M_2 = \frac{45 \times 300 \times 185}{76 \times 266} = 123.54\,kg$

9. (*b*) The total pressure of the mixture of gases using concept of partial pressure = Pressure exerted by O_2 + Pressure exerted by N_2 + Pressure exerted by CO_2

$P = P_{O_2} + P_{N_2} + P_{CO_2}$

$= \frac{n_1 RT}{V} + \frac{n_2 RT}{V} + \frac{n_3 RT}{V}$

$\Rightarrow P = \frac{RT}{V}\left(\frac{16}{32} + \frac{28}{28} + \frac{44}{44}\right) = \frac{5RT}{2V}$

10. [26] The common equilibrium pressure existing in the mixture

$P = \frac{P_1 V_1 + P_2 V_2}{V_1 + V_2} = \frac{2 \times 4.5 + 3 \times 5.5}{10}$

$= \frac{9 + 16.5}{10} = 25.5 \times 10^{-1}\,atm$

11. (*c*) We have given, $\frac{dP}{dV} = -aP$, at $V = V_0$, $P = P_0$

$T_{max} = ?$ for $n = 1$

$\frac{dP}{dV} = -aP$ (Given)

$\frac{dP}{P} = -a\,dV$

On integrating, we get $\int_{P_0}^{P} \frac{dP}{P} = -a\int_0^V dV$

$\ln\left(\frac{P}{P_0}\right) = -a(V) \Rightarrow P = P_0 e^{-aV}$

Also, we know, $PV = nRT$

$(P_0 e^{-aV})V = nRT$

$\Rightarrow T = \frac{P_0 V e^{-aV}}{nR}$

$\Rightarrow \frac{dT}{dV} = 0 \qquad [for\ T_{max}]$

$\Rightarrow \frac{P_0}{nR}\left[\frac{d}{dV}\left\{V \cdot e^{-aV}\right\}\right] = 0$

$\Rightarrow \frac{d}{dV}\left\{Ve^{-aV}\right\} = 0$

$\Rightarrow Ve^{-aV} \times (-a) + e^{-aV}.1 = 0$

$\Rightarrow (-aV + 1)e^{-aV} = 0$

$\Rightarrow V = \frac{1}{a}$

$\therefore T_{max} = \frac{P_0}{nR} \times \frac{1}{a} \times e$

$= \frac{P_0}{naR} \times e^{-1} \quad T_{max} = \frac{P_0}{aeR} \qquad [\because n = 1]$

12. [150] From ideal gas equation $PV = nRT$

So, $P\Delta V + V\Delta P = 0 \Rightarrow \Delta V = \frac{-\Delta P}{P} V$ ... (*i*)

Now, $P\Delta V = -nR\Delta T$

$\Delta V = \frac{nR\Delta T}{P}$ ... (*ii*)

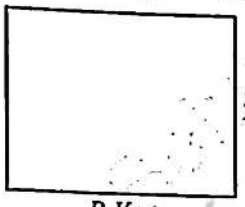
Equation (*i*) and (*ii*) we get

$\Delta T = \Delta P \frac{V}{nR}$

Comparing with $|\Delta T| = C\,|\Delta P|$

$C = \frac{V}{nR} = \frac{300}{2} = 150$ K/atm

13. [05.00] Using, $PV = nRT$, we have



$n_0 = \frac{P_1 V_1}{R \times 250}$

$n' = 0.75n_0 + 0.5n_0$

$= 1.25\ n_0$ moles

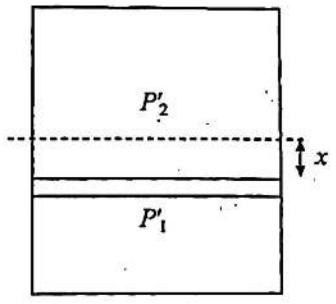
$P_2 \times 2V_1 = (1.25)\frac{P_1 V_1}{R \times 250} \times R \times 2000$

$\Rightarrow \frac{P_2}{P_1} = 5$

14. [6] Assuming temperature remains constant at 300 K

From $P_1 V_1 = P_2 V_2$

$\frac{P_1\left(\frac{V_0}{2}\right)}{T} = \frac{P_1'\left(\frac{V_0}{2} - Ax\right)}{T}$



$(P_1' - P_2')A = mg$

$\left[\frac{P_1\left(\frac{V_0}{2}\right)}{\frac{V_0}{2} - Ax} - \frac{P_2\left(\frac{V_0}{2}\right)}{\frac{V_0}{2} + Ax}\right] A = mg$

$nRT\left[\frac{1}{4-x} - \frac{1}{4+x}\right] = mg$

$(0.1)(8.3)\left[\frac{4+x-4+x}{16-x^2}\right] = mg$

$x^2 + 6x - 16 = 0$

$x = 2 \Rightarrow$ Distance $= 4 + 2 = 6$m

15. (*d*) As piston is stationary. So using *FBD* of the piston,

$P_2 A - P_1 A = mg$

$m = \frac{1}{g}\left(\frac{P_1 A\ell_2}{\ell_2} - \frac{P_2 A\ell_1}{\ell_1}\right)$

$m = \frac{1}{g}\left(\frac{nRT}{\ell_2} - \frac{nRT}{\ell_1}\right)$

$(\because PV = PA\ell = nRT)$

$m = \frac{nRT}{g}\left(\frac{1}{\ell_2} - \frac{1}{\ell_1}\right) = \frac{nRT}{g}\left(\frac{\ell_1 - \ell_2}{\ell_1 \ell_2}\right)$

16. (*a*) $VT = K$

$\Rightarrow V\left(\frac{PV}{nR}\right) = k \Rightarrow PV^2 = K$

$\because C = \frac{R}{1-x} + C_v$

(For polytropic process)

$C = \frac{R}{1-2} + \frac{3R}{2} = \frac{R}{2}$

$\because \Delta Q = nC\Delta T$

$n = 1$ and $C = \frac{R}{2}$

$\Delta Q = \frac{1}{2}R\Delta T$

17. (*d*) RMS velocity of a gas molecule is given by:

$v = \sqrt{\frac{3RT}{M}}$

Let the temperature at which the velocity of hydrogen is equal to the velocity of oxygen at 47°C be T

$\sqrt{\frac{3RT}{2}} = \sqrt{\frac{3R \times (273 + 47)}{32}}$

$T = 20$ K

18. (*b*) $V_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow V_{r.m.s} \propto \frac{1}{\sqrt{M}}$

$\Rightarrow \frac{V_{O_2}}{V_{He}} = \sqrt{\frac{M_{He}}{M_{O_2}}} \Rightarrow \sqrt{\frac{4}{32}} = \frac{1}{2\sqrt{2}}$

@FAKE_CBSE_X @RAJ_EDUNET

19. (b) Given, rms speed

$= \sqrt{\frac{\alpha+5}{\alpha}} \times$ average speed

$\Rightarrow \sqrt{\frac{3RT}{M}} = \sqrt{\frac{\alpha+5}{\alpha}}\sqrt{\frac{8}{\pi}\frac{RT}{M}}$

$\Rightarrow \alpha = 28$

20. (b) As, $\boxed{v_{rms} = \sqrt{\frac{3RT}{M}}}$

$\Rightarrow \boxed{\frac{v_1}{v_2} = \sqrt{\frac{M_2}{M_1}} \Rightarrow \frac{2}{v_2} = \sqrt{\frac{32}{2}}}$

$v_2 = 0.5$ km/s

21. (c) R.m.s speed of a gas molecule,

$V_{rms} = \sqrt{\frac{3RT}{M}}$, therefore $\frac{(V_{rms})_{Ar}}{(V_{rms})_{Cl}}$

$= \sqrt{\frac{M_{Cl}}{M_{Ar}}}$

$\Rightarrow (V_{r.m.s})_{Ar} = 1.33 \times 490 = 651.7$ m/s

22. (c) The rms speed of a gas molecule is given by

$V_{RMS} = \sqrt{\frac{3RT}{M}}$

$V_{RMS} \propto \sqrt{T}$

23. (a) According to question, $v_{r.m.s.} = \sqrt{\frac{3RT}{M}}$

$v_{avg} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{3RT}{M}} = \left(1+\frac{5}{x}\right)^{\frac{1}{2}}\sqrt{\frac{8RT}{\pi M}}$

$\Rightarrow \frac{3\times22}{7\times8} = 1+\frac{5}{x} \Rightarrow x = 28$

24. (d) $v_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow v_{rms} \propto \sqrt{T}$

$\frac{v_0}{v_0'} = \sqrt{\frac{200}{800}}$

$v_0' = 2v_0$

25. (a) Formula of root mean square speed of a molecule of gas.

$V_{rms} = \sqrt{\frac{3k_BT}{m}}$

$= \sqrt{\frac{3\times1.4\times10^{-23}\times300}{4.6\times10^{-26}}} = 523 m/s$

26. (b) Statement-I

$T_1 = -73^\circ C = 200K$

$T_2 = 527^\circ C = 800K$

$\because \frac{V_1}{V_2} = \frac{\sqrt{\frac{3RT_1}{M}}}{\sqrt{\frac{3RT_2}{M}}} \Rightarrow \frac{V_1}{V_2} = \sqrt{\frac{T_1}{T_2}}$

$\therefore \frac{V_1}{V_2} = \sqrt{\frac{200}{800}} = \frac{1}{2} \Rightarrow V_2 = 2V_1$ (True)

Statement-II

$PV = nRT$

whereas, Translational $KE = \frac{3}{2}nRT$ (False)

27. (b) $V_{rms} = \sqrt{\frac{3RT}{M}}$

$\therefore V_{rms} \propto \frac{1}{\sqrt{M}}$

$M_{poly} > M_{dia} > M_{mono}$

neon = 20 . 17 g/mol

Cl = 35 . 45 g/mol

$H.F$ = 146.46 g/mol

So correct relation is

V_{rms} (mono) > V_{rms}(dia) > V_{rms}(poly)

28. (b) $v_{rms} = \sqrt{\frac{3RT}{M}}$ and $v_{mp} = \sqrt{\frac{2RT}{M}}$

29. (b) $v_{rms} = \sqrt{\frac{3RT}{M}}$

$T \to 2T$, $M \to \frac{M}{2}$ then

$v'_{rms} = 2\sqrt{\frac{3RT}{M}} \Rightarrow v'_{rms} = 2V_{rms}$

30. (c) (a) $V_{rms} = \sqrt{\frac{3RT}{M_w}} \Rightarrow V_{rms}$ is same

(b) $\frac{P_1}{P_2} = \frac{N_1}{N_2}$ [a & b only are correct]

31. (c) Given, $m = 5 \times 10^{-17}$ kg, $k = 1.38 \times 10^{-23}$ Jk^{-1}

$V_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3\times1.38\times10^{-23}\times300}{5\times10^{-17}}}$

$= 15$mm/s

32. [12] V_{rms} speed of the molecule of a gas,

$V_{rms} = \sqrt{\frac{3RT}{M}}$

$V_{rms} \propto \sqrt{T}, T_1 = 127^\circ C = 400\ K$

$V_{rms}' = 2V_{rms}$, $m = 0.056$kg $= 56$g

$T_2 = 4T_1 = 4 \times 400 = 1600$ K

$Q = nC_v\Delta T = \left(\frac{m}{M}\right)C_v\Delta T$

$= \left(\frac{56}{28}\right)\frac{5}{2}R\Delta T$

$= 2\times\frac{5}{2}\times2\times1200$

$= 12 \times 10^3$ cal $= 12$ k cal

33. (b) $V_{rms} = \sqrt{\frac{3RT}{M}}$

At constant T, $V_{rms} \propto \frac{1}{\sqrt{M}}$

$M_H = 1$, $M_O = 16$, $M_{CO_2} = 44$

$V_H : V_O : V_{CO_2} = \frac{1}{\sqrt{1}} : \frac{1}{\sqrt{16}} : \frac{1}{\sqrt{44}}$

$= 1 : \frac{1}{4} : \frac{1}{2\sqrt{11}}$

Therefore, $V_H > V_O > V_{CO_2}$

34. (c) Root mean square speed is given by

$v = \sqrt{\frac{3RT}{M}}$

Since, $m_A < m_B < m_C$

$\therefore v_A > v_B > v_C \Rightarrow \frac{1}{v_A} < \frac{1}{v_B} < \frac{1}{v_C}$

35. (c) Translational kinetic energy will be equal to rotational kinetic energy corresponds to each degree of freedom

36. (b) We know that, $v_{rms} = \sqrt{\frac{3kT}{m}}$

when temperature, T is constant,

$\frac{(v_{rms})_{O_2}}{(v_{rms})_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} = \sqrt{\frac{2}{32}}$

$\Rightarrow (v_{rms})_{H_2} = 4 \times (v_{rms})_{O_2} = 4 \times 160 = 640$m/s

37. (d) We know that,

$v_{rms} = \sqrt{\frac{3RT}{M}}$ and $v_{av} = \sqrt{\frac{8RT}{\pi M}}$

$\therefore \frac{v_{rms}}{v_{av}} = \frac{\sqrt{\frac{3RT}{M}}}{\sqrt{\frac{8RT}{\pi M}}} = \sqrt{\frac{3\pi}{8}}$

38. [400] Given, $T = 27^\circ C = 300$K; P = 1 atm $= 10^5$ N/m^2

$v_{rms} = 200$ m/s

As we know, $\frac{200}{v'_{rms}} = \sqrt{\frac{T}{T'}} = \sqrt{\frac{300}{400}}$

$v'_{rms} = 200 \times \frac{2}{\sqrt{3}}$

On comparing with $\frac{x}{\sqrt{3}}$ ms^{-1}, we get x = 400.

39. [25] Mean free path,

$\lambda \propto \frac{1}{d^2}$

$\therefore \frac{\lambda_1}{\lambda_2} = \frac{d_2^2}{d_1^2} = \frac{25}{100} = 25\times10^{-2}$

40. (c) $\tau_{mean} = \frac{\ell_{mean}}{v}$

$\because \ell_{mean} = \frac{1}{\sqrt{2}\pi nD^2}$ and $V \propto \sqrt{T}$

@TAKE_CBSE_X @RAJ_EDUNET

$\therefore \tau_{mean} = \frac{\ell_{mean}}{v} \Rightarrow \tau_{mean} \propto \frac{1}{\sqrt{T}}$

41. [40.93] V_{rms} for $N_2 = \sqrt{\frac{3KT}{28}} = \sqrt{\frac{3\times K\times 573}{28}}$

v_{rms} for $H_2 = \sqrt{\frac{3KT_1}{2}}$

v_{rms} for $N_2 = V_{rms}$ for H_2

$\therefore \frac{3KT_1}{2} = \frac{3K\times 573}{28} \Rightarrow T_1 = \frac{573}{14} K$

$T_1 = 40.93$ kelvin

42. (a) The ratio of rms speed of helium and organ gas.

$\frac{(V_{rms})_{He}}{(V_{rms})_{Ar}} = \sqrt{\frac{M_{Ar}}{M_{He}}}$ ($\therefore M_{Ar}$ = atomic mass of Argon gas and M_{He} is atomic mass of helium gas)

$= \sqrt{\frac{40}{4}} = \sqrt{10} = 3.16$

43. (b) $A' = 7 \times A_1 = 7 \times 5.29 = 37.03$

Rounding off to 3 significant figures

$A = 37.0\ cm^2$

44. (d) RMS speed of molecules, $v_{rms} = \sqrt{\frac{3RT}{M_w}}$

$\therefore v_{rms} \propto \sqrt{T}$

$\frac{V_2}{V_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{127+273}{227+273}}$

$\frac{v}{200} = \sqrt{\frac{500}{400}}$

$v = 100\sqrt{5} m/s$

45. (a) Density of molecules of gas, $n(r) = n_0 e^{-\alpha r^4}$

$\therefore$ Total number of molecule

$= \int_0^\infty n(r)dV = \int_0^\infty n_0 e^{-\alpha r^4} 4\pi r^2 dr$

$\therefore$ Number of total molecules is directly proportional to $n_0 e^{-\alpha r^4}$

46. (b) Given: $V_{rms} = V_{escape}$

$\sqrt{\frac{3RT}{m}} = \sqrt{2gR_e} \Rightarrow T = \frac{2mgR_e}{3R}$

$T = \frac{2\times 2\times 10^{-3}\times 10\times 6400\times 10^3}{3\times 8.314}$

$T = 10^4$ Kelvin

47. (c) We have given that, mass = 15g, $T = 27°C$.

Amount of heat transferred to the gas, ΔQ

$= \frac{f}{2} nR\Delta T = \frac{5}{2}\left(\frac{15}{28}\right)(8.3)(1200 - 300)$

$= 10000$ J.

48. (d) Here we have,

Mean free path $= \frac{RT}{\sqrt{2}\pi d^2 N_A P}$

$KE = \frac{f}{2} nRT$

49. (b) $\because$ Hydrogen and oxygen are diatomic.

$\Rightarrow E_{av} = \frac{5}{2} kT$

$\Rightarrow$ Ratio = 1 : 1

50. (a) Average KE per molecule of a gas $= \frac{3}{2} kT \Rightarrow K \cdot E \propto T$ $\frac{K\cdot E_{Ar}}{K\cdot E_{H}} = \frac{1}{1}$

51. (c) Kinetic energy $= \frac{f}{2} kT$, T is absolute temperature.

$K.E \propto T$

$\frac{K.E_1}{K.E_2} = \frac{T_1}{T_2} \Rightarrow \frac{1}{2} = \frac{300}{T}$

$T = 600\ K$

$T = 327°\ C$

52. (a) Translational $K.E$ of a molecule = $\frac{3}{2} k_B T$ which is independent of nature, pressure and volume, but depends on temperature.

53. (b) $\lambda = \frac{kT}{\sqrt{2}\pi d^2 P}$

54. (a) $KE_{avg} = \frac{3}{2} KT$

$P = \frac{1}{3}\rho V_{rms}^2$

55. (d) The average momentum of a molecule in the sample of an ideal gas is zero because the average velocity is zero. Therefore average momentum of a molecule in a sample of an ideal gas is independent of temperature.

$v = \sqrt{\frac{3RT}{M}}$

$v' = \sqrt{\frac{3R2T}{(M/2)}} = 2\frac{\sqrt{3RT}}{M} = 2v$

56. (b) On the basis of kinetic theory of gases, the gas exerts pressure because its molecule: suffer change in momentum when impinge on the walls of container.

57. (d) Given, $V = 1$ litre $= 1\times 10^{-3} m^3$, $T = 300$ K, $P = 2$ atm $= 2\times 1.013 \times 10^5$ N/m^2

$KE = 2\times 10^{-9}$ J/molecule, Let no. of molecule be N.

no. of moles $(n) = N/N_A$

$N = nN_A$

From, $PV = nRT$

$n = \frac{PV}{RT} = \frac{PV}{N_A K_B T}$

[$\because K_B \rightarrow$ Boltzman constant]

Formula of mean Kinetic energy

$K.E. = \frac{3}{2} K_B T$

$\therefore \frac{3}{2} K_B T = 2\times 10^{-9}$

$K_B T = \frac{4\times 10^{-9}}{3}$

Number of molecules $N = nN_A$

$= \frac{PV}{N_A K_B T} \times N_A$

$= \frac{PV}{K_B T} = \frac{2\times 1.013\times 10^5 \times 10^{-3}}{\frac{4}{3}\times 10^{-9}}$

$\approx \frac{3}{2}\times 10^{11}$

58. [3600] $\Delta K.E = \Delta U$

$\frac{1}{2} mv^2 = nC_v \Delta T = \frac{m}{M} \times \frac{3}{2} R\Delta T$

$\therefore \Delta T = \frac{M}{3}\frac{v^2}{R} = 4\times\frac{30^2}{3R} = \frac{3600}{3R} K.$

59. (d) $PV = NkT$

$E = \frac{3}{2} kT$

$N = \frac{3PV}{2E}$ $(P = hrg)$

$= 4\times 10^{18}$

60. [266.67]

$\left(0.1\times\frac{3}{2}R\times 200\right) + \left(0.05\times\frac{3}{2}R\times 400\right)$

$= 0.15\times\frac{3}{2} R.T_f \Rightarrow (20 + 20) = 0.15\ T_f$

$\Rightarrow T_f = \frac{40}{15}\times 100 = 266.67$

61. (a) Using law of equipartition energy

$\frac{1}{2} m(v_{rms}^2) = 3\times\frac{1}{2} k_B T$

$T = \frac{mv_{rms}^2}{3k_B}$

62. (b) For monoatomic molecule

$K.E_{avg} = \frac{3}{2} K_B T$

$\Rightarrow T = \frac{0.414\times 1.6\times 10^{-19}\times 2}{3\times 1.38\times 10^{-23}} = 3200$ K

63. (c) As f = 5 for diatomic gases

$\therefore$ Kinetic energy $= \frac{f}{2}$ nRT

$= \frac{5}{2} \times 1 \times 8.31 \times 300$ J $= 6232.5$ J

@FAKE_CBSE_X @RAJ_EDUNET

64. (c) Degree of freeom of polyatomic gas, $f = 6$

Degree of freedom of monoatomic gam, $f = 3$

$$f_{eq} = \frac{n_1 f_1 + n_2 f_2}{n_1 + n_2}$$

For diatomic gas $f_{eq} = 5$

$$5 = \frac{(N)(6) + (2)(3)}{N + 2}$$

$$5N + 10 = 6N + 6$$

$$N = 4$$

65. (a) The parameter that remains the same for molecules of all gases at a given temperature is kinetic energy. Iis given by:

$$KE = \frac{f}{2}kT$$

66. (c) Total internal energy, $U = nC_vT$

$$\Rightarrow U = n_1C_{v_1}T + n_2C_{v_2}T$$

$$\Rightarrow 8 \times \frac{3R}{2} \times T + 6 \times \frac{5R}{2} \times T = 27RT$$

67. (a) C_v for monoatomic and diatomic gases are 3/2 R and 5/2 R respectively.

$$C_V = \frac{n_1C_{v_1} + n_2C_{v_2}}{n_1 + n_2}$$

$$= \frac{2 \times \frac{3}{2}R + 6 \times \frac{5}{2}R}{2 + 6} = \frac{9}{4}R$$

68. (b) D.O.F of CH_4. [Non-Linear polyatomic Moleule.]

Translational D.O.F = 3

Rotational D.O.F = 3

69. (d) D.O.f $(f) = 5 + 2(3N - 5)$

$f = 5 + 2(3 \times 2 - 1) = 7$

Energy of N molecule $= N\frac{f}{2}K_BT$

$$= 10\left(\frac{f}{2}K_BT\right) = 10\left(\frac{7}{2}K_BT\right)$$

$= 35\ K_BT$

70. (c) The required ratio of specific heat at constant volume,

$$\frac{(C_v)_{mono}}{(C_v)_{dia}} = \frac{\frac{3}{2}R}{\frac{5}{2}R} = \frac{3}{5}$$

71. (b) Kinetic energy of the gas molecules,

$$K.E = \frac{nfRT}{2}, K.E\ \alpha\ T$$

$T_i = -78°C \rightarrow 273 + [-78°C] = 195\ K$

To double the K.E energy temperature of the particle also become double

$T_f = 390\ K = 117°C$

72. [121] At constant pressure, work done $W = nR\Delta T = 66$

Internal energy,

$$\Delta U = n(C_v)_{mix}\Delta T$$

$$(C_v)_{mix} = \frac{n_1C_{v_1} + n_2C_{v_2}}{n_1 + n_2}$$

$$= \frac{2 \times \frac{3}{2}R + 1 \times \frac{5}{2}R}{3}$$

$$(C_v)_{mix} = \frac{11}{6}R$$

$$\Delta U = \frac{11}{6}(nR\Delta T) = \frac{11}{6} \times 66 = 121\ J.$$

73. (c) For a monoatomic gas $\gamma_1 = \frac{5}{3}$

For a diatomic gas at low temperature

$$\gamma_2 = \frac{7}{5}$$

$$\therefore \frac{\gamma_1}{\gamma_2} = \frac{\frac{5}{3}}{\frac{7}{5}} = \frac{25}{21}$$

74. (d) A diatomic gas molecule has three translational degree of freedom, two rotational degree of freedom & given in the question that it has one vibrational mode so there are two additional degrees of freedom corresponding to one vibrational mode, so total degrees of freedom = 7

$$\Rightarrow C_v = \frac{7R}{2}$$

75. (d) Internal energy of oxygen (diatomic)

$$U_1 = \frac{5}{2}(n)RT = \frac{5}{2}(2)RT = 5RT$$

Internal energy of argon (monoatomic)

$$U_2 = \frac{3}{2}(n)RT = \frac{3}{2}(4)RT = 6RT$$

Total energy $U = U_1 + U_2$

$U = 5\ RT + 6RT = 11\ RT$

76. (a) $Q = nC_p\Delta T$

$$735 = n \times \frac{7R}{2} \times \Delta T$$

$$105 = \frac{n}{2}R\Delta T \quad ...(i)$$

Since diatomic gas has degree of freedom = 5

$$\Delta U = \frac{5n}{2}R\Delta T$$

from equation (i)

$$\Delta U = 5 \times \left(\frac{n}{2}R\Delta T\right) = 5 \times 105 = 525$$

77. (b) γ is independent of temperature

78. (c)

Type of gases	Degree of freedom		
	Translational	Rotational	Vibrational
Mono atomic	3	0	0
Rigid diatomic	3	2	0
Non-rigid diatomic	3	2	1
Polyatomic	3	3	More than 6

79. (b) Given,

Moles of He, $n_1 = 2$ & Moles of H_2, $n_2 = 4$

Speed of sound in a gas, $v_s = \sqrt{\frac{\gamma RT}{M}}$

Rms speed of gas molecules,

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

According to question,

$$v_{rms} = \sqrt{2}v \Rightarrow \sqrt{\frac{3RT}{M}}$$

$$= \sqrt{2}\sqrt{\frac{\gamma RT}{M}} \Rightarrow \gamma = \frac{3}{2}$$

Using, $\gamma = 1 + \frac{2}{f_{mix}}$

$$f_{mix} = \frac{f_1 \times n_1 + f_2 \times n_2}{n_1 + n_2} = \frac{2 \times 3 + 5 \times n}{2 + n}$$

$$\therefore \gamma = 1 + \frac{4 + 2n}{6 + 5n}$$

$$\frac{1}{3} = \frac{7n + 10}{6 + 5n}$$

$n = 2$

80. (c) We have, $m_{N_2} = 14g$, $T = 27°C = 300K$

$V_{rms} \propto \sqrt{T}$

To double the V_{rms}, $T_f = 4T_i = 4 \times 300$ $= 1200K$

$\therefore Q = nC_v\Delta T$

$$= \left(\frac{14}{28}\right)\frac{5}{2}R \times (1200 - 300)$$

$= 1125R = 1125 \times 8.32 = 9360J$

81. [9] $\sigma AT^4 = -ms\frac{dT}{dt}$

$$\int_{200}^{100} \frac{dT}{T^4} = \int_0^{t_1} kdt$$

$$\left[\frac{1}{3T^3}\right]_{200}^{100} = kt_1$$

$$\frac{1}{3}\left(\frac{1}{100^3} - \frac{1}{200^3}\right) = kt_1$$

@FAKE_CBSE_&_FREE_EDU_INT

$$\left[\frac{1}{3T^3}\right]_{200}^{50} = kt_2$$

$$\frac{1}{3}\left(\frac{1}{50^3}-\frac{1}{200^3}\right)=kt_2$$

$$\frac{t_2}{t_1}=\left(\frac{200^3-50^3}{200^3-100^3}\right)\frac{100^3}{50^3}=9$$

82. (*b*) Molar heat capacity of A at constant volume $=\frac{5R}{2}$

Molar heat capacity of B at constant volume $=\frac{7R}{2}$

Dividing both $\frac{C_V^A}{C_V^B}=\frac{5}{7}$

83. (*a*)

	Helium	Oxygen
Moles	n	$2n$
C_v	3/2 R	5/2 R
C_p	5/2 R	7/2 R

$$\gamma_{mix}=\frac{(C_V)mix}{(C_P)mix}=\frac{n_1C_{P_1}+n_2C_{P_2}}{n_1C_{V_1}+n_2C_{V_2}}$$

$$=\frac{n\left(\frac{5}{2}R\right)+2n\left(\frac{7}{2}R\right)}{n\left(\frac{3}{2}R\right)+2n\left(\frac{5}{2}R\right)}=\frac{5+14}{3+10}=\frac{19}{13}$$

84. (*a*) Given, $n_1=2$ and $n_2=3$

$$\gamma_{mixture}=\frac{n_1C_{P_1}+n_2C_{P_2}}{n_1C_{V_1}+n_2C_{V_2}}$$

$$=\frac{n_1\frac{\gamma_1R}{\gamma_1-1}+n_2\frac{\gamma_2R}{\gamma_2-1}}{\frac{n_1R}{\gamma_1-1}+\frac{n_2R}{\gamma_2-1}}$$

$$\left[\therefore C_P=\frac{R\gamma}{\gamma-1}\text{ and }C_V=\frac{R}{\gamma-1}\right]$$

$$\gamma_{mix}=\frac{2\times\frac{5R}{2}+3\times4R}{2\times\frac{3R}{2}+3\times3R}=\frac{17}{12}=1.42$$

85. (*c*) For Monatomic $\frac{C_v}{C_p}=\frac{5}{3}$ Triatomic $\frac{C_v}{C_p}=\frac{4}{3}$

For Diatomic

Rigid $\frac{C_v}{C_p}=\frac{7}{5}$

Non Rigid $\frac{C_v}{C_p}=\frac{9}{7}$

86. (*a*) $160=nC_p50$ ...(*I*)

$240=nC_v100$ ...(*II*)

From (*I*) and (*II*),

$$\frac{160}{240}=\frac{C_P}{C_v}\times\frac{1}{2}$$

$$\Rightarrow \gamma=\frac{C_P}{C_v}=1+\frac{2}{f}=\frac{4}{3}\Rightarrow f=6$$

87. (*b*) $E=3\times\frac{5}{2}RT+5\times\frac{3}{2}\times RT=15RT$

88. (*a*) $U=\frac{nfRT}{2}$

$f=6$ (for triatomic) $\Rightarrow U=3RT$

89. (*d*) $f=5$

$\therefore U=\frac{5}{2}RT$

and $\gamma=1+\frac{2}{f}=1+\frac{2}{5}=\frac{7}{5}$

90. (*) Data insufficient. Degree of freedom is not given.

Energy $=\frac{f}{2}PV$

91. (*c*) Heat loss = Heat gain

$192\times S\times(100-21.5)$

$=128\times394\times(21.5-8.4)+240\times4200\times(21.5-8.4)$

$\Rightarrow S=916\ \text{Jkg}^{-1}\text{K}^{-1}$

92. (*a*) Total energy of the system is

$U_{total}=U_{oxygen}+U_{argon}$

$$=\frac{3\times5\times RT}{2}+\frac{5\times3\times RT}{2}$$

$$=RT\left(\frac{15}{2}+\frac{15}{2}\right)=15\ RT$$

93. (*c*) We have given that, mass = 15*g*, $T=27°C$.

Amount of heat transferred to the gas, ΔQ

$$=\frac{f}{2}nR\Delta T$$

$$=\frac{5}{2}\left(\frac{15}{28}\right)(8.3)(1200-300)=10000\ \text{J}.$$

94. (*c*) Here, we have mean free path constant [Assume]

$f\propto v\propto\sqrt{T}$

$$\frac{f_1}{f_2}=\sqrt{\frac{T_1}{T_2}}=\sqrt{\frac{300}{400}}$$

[Here, T_1 and T_2 is in K]

$$f_2=\sqrt{\frac{4}{3}}=f_1=\frac{2}{\sqrt{3}}Z$$

95. (*c*) Mean free path $=\frac{1}{\sqrt{2}\pi d^2n}$

96. (*b*) Formula of Mean free path of a molecule of the gas

$$\lambda=\frac{RT}{\sqrt{2}\pi d^2PN_A}\Rightarrow\lambda\propto T$$

$$\frac{1500d}{\lambda}=\frac{273}{373}$$

$\lambda=2049\ d$

97. (*b*) Collision frequency,

$$f=\frac{V}{\lambda}=\frac{V}{\left(\frac{1}{\sqrt{2}\pi d^2n_v}\right)}=\sqrt{2}\pi d^2vn_v$$

$\therefore$ frequency is directly proportional to number of air molecules.

$$\therefore\frac{f}{f'}=\frac{n}{n_v'}=\frac{3\times10^{19}}{12\times10^{19}}=\frac{3}{12}=0.25$$

98. (*d*) Mean free path $\lambda=\frac{kT}{\sqrt{2}\pi d^2P}$

$$=\frac{1.38\times10^{-23}\times300}{1.4\times3.14\times\left(0.3\times10^{-9}\right)^2\times1.01\times10^5}$$

$\therefore\lambda=102$ nm

99. (*c*) Mean free path is independent of temperature and relaxation time decreases as temperature increases.

100. (*d*) As mean free time

$\tau\propto\frac{1}{\sqrt{T}}$

So, graph (d) depicts the right behaviour.

101. (*a*) Mean free time $=\frac{1}{\sqrt{2}n\pi d^2V_{rms}}$

Therefore, $\frac{t_{Ar}}{t_{xe}}=\frac{d_{xe}^2}{d_{Ar}^2}\times\sqrt{\frac{m_1}{m_2}}$

$$=\left(\frac{0.1}{0.07}\right)^2\times\sqrt{\frac{40}{140}}=1.09$$

Hence, the nearest answer is 1.83.

102. (*a*) $v=\frac{V_{av}}{\lambda}$

$$\lambda=\frac{RT}{\sqrt{2}\pi\sigma^2N_AP}$$

$\sigma=2\times0.3\times10^{-9}$

$$P=\frac{RT}{V}\Rightarrow\lambda=\frac{V}{\sqrt{2}\pi\sigma^2N_A}$$

$$V_{av}=\sqrt{\frac{8}{3\pi}}\times V_{rms}$$

$$\therefore v=\frac{200\times\sqrt{2}\pi\times\sigma^2N_A}{25\times10^{-3}}\times\sqrt{\frac{8}{3\pi}}$$

$=0.1768\times10^{10}/\text{sec}\sim10^{10}$

Hence, option (*a*) is correct answer.

@FAKE_CBSE_K @RAJ_EDUNET

1. (*d*) $\rho = \frac{pM}{RT} \therefore \rho \propto pM$

or $\frac{\rho_1}{\rho_2} = \left(\frac{\rho_1}{\rho_2}\right)\left(\frac{M_1}{M_2}\right) = \left(\frac{2}{3}\right)\left(\frac{4}{3}\right) = \frac{8}{9}$

2. (*b*) $v_{rms} = \sqrt{\frac{3RT}{M}}$

i.e. $v_{rms} \propto \sqrt{T}$

When temperature is increased from 120 K to 480 K (i.e. four times), the root mean square speed will become $\sqrt{4}$ or 2 times i.e. $2v$.

3. (*c*) Average translational kinetic energy of an ideal gas molecule is $\sqrt{\frac{3}{2}}kT$ which depends on temperature only. Therefore, if temperature is same, translational kinetic energy of O_2 and N_2 both will be equal.

4. (*d*) The average translational KE $= \frac{3}{2}kT$ which is directly proportional to T, while rms speed of molecules is given by

$v_{rms} = \sqrt{\frac{3RT}{M}}$ i.e. $v_{rms} \propto \sqrt{T}$

When temperature of gas is increased from 300 K to 600 K (i.e. 2 times), the average translational KE will increase to 2 times and rms speed to $\sqrt{2}$ or 1.414 times.

$\therefore$ Average translational KE
$= 2 \times 6.2 \times 10^{-21}\ J = 12.42 \times 10^{-21}\ J$
and $v_{rms} = (1.414)\ (484)$ m/s.
≈ 684 m/s

5. (*a*) Average kinetic energy per molecule per degree of freedom $= \frac{1}{2}kT$. Since, both the gases are diatomic and at same temperature (300 K), both will have the same number of rotational degree of freedom i.e. two. Therefore, both the gases will have the same average rotational kinetic energy per molecule

$= 2 \times \frac{1}{2}kT$ or kT

$\Rightarrow$ Thus, ratio will be 1 : 1.

6. (*b*) The average speed of molecules of an ideal gas is given by

$\langle v \rangle = \sqrt{\frac{8RT}{\pi M}}$

i.e. $\langle v \rangle \propto \sqrt{T}$ for same gas.

Since, temperatures of A and C are same, average speed of O_2, molecules will be equal in A and C i.e. v_1.

7. (*a, b, d*) Total internal energy

$U = \frac{f_1}{2}nRT + \frac{f_2}{2}nRT$

$(U_{ave})_{per\ mole} = \frac{U}{2n}$

$= \frac{1}{4}[5RT + 3RT] = 2RT$

(*b*) $\gamma_{mix} = \frac{n_1 C_{p_1} + n_2 C_{p_2}}{n_2 C_{V_1} + n_2 C_{V_2}}$

$= \frac{(1)\frac{7R}{2} + (1)\frac{5R}{2}}{(1)\frac{5R}{2} + (1)\frac{3R}{2}} = \frac{3}{2}$

$M_{mix} = \frac{n_1 M_1 + n_2 M_2}{n_1 + n_2}$

$= \frac{M_1 + M_2}{2} = \frac{2+4}{2} = 3$

Speed of sound $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \sqrt{\frac{\gamma}{M}}$

$\frac{V_{mix}}{V_{He}} = \sqrt{\frac{\gamma_{mix}}{\gamma_{He}} \times \frac{M_{He}}{M_{mix}}}$

$= \sqrt{\frac{3/2}{5/3} \times \frac{4}{3}} = \sqrt{\frac{6}{5}}$

(*d*) $V_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow V_{rms} \propto \frac{1}{\sqrt{M}}$

$\frac{V_{Hc}}{V_H} = \sqrt{\frac{M_H}{M_{Hc}}} = \sqrt{\frac{2}{4}} = \frac{1}{\sqrt{2}}$

8. (*c, d*) $v_{rms} = \sqrt{\frac{3RT}{M}}, \bar{v} = \sqrt{\frac{8}{\pi}\frac{RT}{M}} \approx \sqrt{\frac{2.5RT}{M}}$

and $v_p = \sqrt{\frac{2RT}{M}}$

From these expressions we can see that,

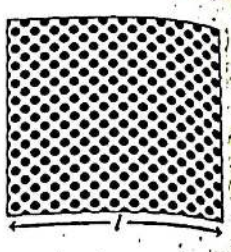
$v_p < \bar{v} < v_{rms}$

Secondly, $v_{rms} = \sqrt{\frac{3}{2}}v_p$

and average kinetic energy of a gas molecule

$= \frac{1}{2}mv_{rms}^2 = \frac{1}{2}m\left(\sqrt{\frac{3}{2}}v_p\right)^2 = \frac{3}{4}mv_p^2$

9. Volume of the box = 1 m^3
Pressure of the gas = 100 N/m^2
Let T be the temperature of the gas.



Then,

(*a*) Time between two consecutive collisions with one wall $= \frac{1}{500}$ s

This time should be equal to $\frac{2l}{v_{rms}}$ where l is the side of the cube.

$\frac{2l}{v_{rms}} = \frac{1}{500}$

or $v_{rms} = 1000$ m/s (as $l = 1$m)

or $\sqrt{\frac{3RT}{M}} = 1000$

$\therefore T = \frac{(1000)^2 M}{3R}$

$= \frac{(10)^6 (4 \times 10^{-3})}{3\left(\frac{25}{3}\right)} = 160K$

(*b*) Average kinetic energy per atom

$= \frac{3}{2}kT = \frac{3}{2}(1.38 \times 10^{-23})(160)J$

$= -3.312 \times 10^{-21}$ J

(*c*) From $pV = nRT = \frac{m}{M}RT$

We get mass of helium gas in the box

$m = \frac{pVM}{RT}$

Substituting the values, we get

$m = \frac{(100)(1)(4)}{(25/3)(160)} = 0.3$ g

10. Formula based:

$n = \frac{P}{kT}$ & V_{rms}

$= \sqrt{\frac{3N_A kT}{M_n}}$. Recall the assumption of KTG.

Kinetic energy changed to internal energy

(*a*) $n = P/kT$

where k = Boltzmann constant
$= 1.38 \times 10^{-23}$ J/mol/K
$P = 1$ atmosphere $= 1.01 \times 10^5$ N/m²
$T = 27°C = 300°K$

@TAKE_CBSE_KOMAL_EDUNET

$$n=\frac{1.01\times10^5}{1.38\times10^{-23}\times300}$$

$$=2.44\times10^{25}\ m^{-3}$$

The root mean square velocity V_{rms} is given by

$$V_{rms}=\sqrt{\left(\frac{3RT}{M_m}\right)}=\sqrt{\left(\frac{3N_Ak T}{M_m}\right)}$$

$(\because R=N_AK)$

N_A = Avogadro number = 6.02×10^{23} molecule/mole

$M_m=32gm=32\times10^{-3}$ kg.

$$V_{rms}=\sqrt{\left(\frac{36.02\times10^{23}\times1.38\times10^{-23}\times300}{32\times10^{-3}}\right)}$$

$=483.4$ m/s

Since each molecule may be moving at a given instant, along any of the six directions (i.e. $+X$, $+Y$ and $+Z$) only $(1/6)^{th}$ of the total molecules contained in the volume along positive and negative x, y, z directions, move towards the wall.

The number of collisions per second with one square meter area of the vessel wall will be

$$=\frac{1}{6}\times n\times V_{rms}=\frac{1}{6}\times2.44\times10^{25}\times483.4$$

$=1.97\times10^{27}$

(b) $K.E_1=\frac{1}{2}mv_0^2$

Heat energy gained $=C_v\Delta T=C_v\times1=C_v$

$$C_p-C_v=R\text{ or }C_v=\frac{R}{\gamma-1}$$

$$\therefore\gamma=1.41;\frac{1}{2}mv_0^2=C_v=\frac{R}{\gamma-1}$$

$$v_0=\sqrt{\left(\frac{2R}{m(\gamma-1)}\right)}=\sqrt{\left(\frac{2\times8.31\times1}{32\times10^{-3}\times141-1}\right)}$$

$=35.6$m/sec.

II. [False] $v_{rms}=\sqrt{\frac{3RT}{M}}$ or $v_{rms}\propto\sqrt{\frac{T}{M}}$

When oxygen gas dissociates into atomic oxygen its atomic mass M will remain half. Temperature is doubled. So, from Eq. (i) v_{rms} will become two times.

12. [False] $v_{rms}=\sqrt{\frac{3RT}{M}}$

It not only depends on T but also on M.

13. [False] $v_{rms}=\sqrt{\frac{3RT}{M}}$

So, v_{rms} not only depends on T but also on M.

14. (b) Total translational kinetic energy,

$$=\frac{3}{2}nRT=\frac{3}{2}pV=1.5pV$$

15. (a) As there is a small hole at the top of the cylinder, thus the piston is always at the atmospheric pressure i.e p_0 irrespective of the movement of the piston.

16. (d) Pressure inside the piston when the piston is sealed at a distance of $2L$ is P_0.

Let p be the pressure at equilibrium.

Then $pAl=P_0(2AL)\Rightarrow p=\frac{2P_0L}{l}$

Considering piston's equilibrium:

Weight + Downward pressure force = Upwards pressure force

$Mg+p(\pi R^2)=P_0(\pi R^2)$

Inserting the expression of p gives:

$$l=\left(\frac{P_0\pi R^2}{\pi R^2P_0-Mg}\right)(2L)$$

17. (c) Pressure is at all points at same horizontal level within a liquid.

$=P_0+\rho g(L_0-H)$

Applying Boyle's Law, $PV=$ constant

$P_0(AL_0)=(P_0+(L_0-H)\rho g\,(A(L_0-H))$

$\Rightarrow\rho g(L_0-H)^2+P_0(L_0-H)-L_0P_0=0$

18. (c) $pV=nRT$

or $p=\frac{nRT}{V}$ or $p\propto T$

if V and n are same. Therefore, if T is doubled, pressure also becomes two times i.e. $2p$.

19. (a, c) For one mole of an ideal gas $pV=RT$

The coefficient of volume expansion at constant pressure is given by,

$$\left(\frac{\Delta V}{\Delta T}\right)_p=\frac{R}{p}=\text{ constant}\qquad\text{[option (a)]}$$

The average translational kinetic energy per molecule is $(3/2)kT$ and not $3\ kT$. With decrease of pressure, volume of the gas increases so its mean free path also increases. The average translational kinetic energy of the molecules is independent of their nature, so each component of the gaseous mixture will have the same value of average translational kinetic energy.

20. [45.53] Given: $T_1=273.16\ K$, $P_1=3.0\times10^4$ N/m², $P_2=3.5\times10^4$ N/m²

In the case of a gas thermometer, the volume of the gas container remains constant.

$$\therefore\frac{P_1}{T_1}=\frac{P_2}{T_1}$$

$\Rightarrow T_2=318.6\ K=45.53°C$

21. [4.0744, 23.926] $m_{Ne}+m_{Ar}=28$ gm

$PV=(n_{Ne}+n_{Ar})RT$

$$\frac{PV}{RT}=\frac{m_{Ne}}{20}+\frac{m_{AR}}{40}=\frac{10^5\times0.02}{8.314\times300}$$

$2m_{Ne}+m_{Ar}=32.0744$

$m_{Ne}=4.0744$

$m_{Ar}=23.926$

22. [75.4] Let A be the area of cross-section of the tube.

When the tube is horizontal, the 5 The cm column of Hg is in the middle.

So length of air column on either side at pressure

$$P=\frac{46+44.5}{2}=45.25\text{ cm}$$

When the tube is held at 60° with the vertical, the lengths of air columns at the bottom and the top are $44.5cm$ and $46cm$ respectively.

If P_1 and P_2 are their pressures, then

$P_1-P_2=5\cos60°=50\times\frac{1}{2}=\frac{5}{2}$ cm of Hg

By using Boyle's law for constant temperature,

$PV=P_1V_1=P_2V_2$

$P\times A\times45.25=P_1\times A\times44.5=P_2\times A\times46$

$$\therefore\frac{P\times45.25}{44.5}-\frac{P\times45.25}{46}=\frac{5}{2}$$

or $P=\frac{5\times44.5\times46}{2\times45.25\times1.5}=75.4$ cm of Hg.

23. [83.75] At first, at $273K$ the mole in each bulb

$$=\frac{n_{total}}{2}=\frac{1}{2}\cdot\frac{P.2V}{RT}=\frac{76V}{273\times R}$$

On heating the 2nd bulb, some mole of gas is transferred to another bulb until the pressure of both bulbs becomes the same.

$$\therefore n_1=\frac{P\times V}{273R}\text{ and }n_2=\frac{PV}{R\times335}$$

$n_{total}=n_1+n_2$

$$\Rightarrow2\times\frac{76V}{273R}=\frac{P\times V}{273R}+\frac{PV}{335\times R}$$

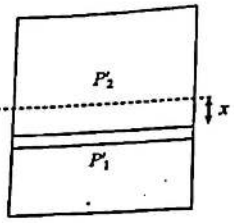
$\Rightarrow P=83.75$ unit of Ag.

24. [6] Assuming temperature remains constant at 300 K

From $P_1V_1=P_2V_2$

$$\frac{P_1\left(\frac{V_0}{2}\right)}{T}=\frac{P_1'\left(\frac{V_0}{2}-Ax\right)}{T}$$

@FAKE_CBSE_K @RJ_EDUNET



$(P_1' - P_2')A = mg$

$$\left[\frac{P_1\left(\frac{V_0}{2}\right)}{\frac{V_0}{2}-Ax} - \frac{P_2\left(\frac{V_0}{2}\right)}{\frac{V_0}{2}+Ax}\right]A = mg$$

$$nRT\left[\frac{1}{4-x} - \frac{1}{4+x}\right] = mg$$

$$(0.1)(8.3)\left[\frac{4+x-4+x}{16-x^2}\right] = mg$$

$$3\left(\frac{2x}{16-x^2}\right) = 1$$

$6x = 16 - x^2$

$x^2 + 6x - 16 = 0$

$x = 2$

Distance $= 4 + 2 = 6$m

25. $Vp^2 =$ constant

Putting, $p = \frac{nRT}{V}$, we have $\frac{T^2}{V}$ = constant

or $T \propto \sqrt{V}$

So, if V is doubled, T becomes $\sqrt{2}$ times.

26. Pressure of one gas = Pressure of other gas.

$$\Rightarrow \frac{n_1RT}{v_1} = \frac{n_2RT}{v_2} \Rightarrow \frac{n_1}{v_1} = \frac{n_2}{v_2}$$

$$\Rightarrow \frac{w}{32} \times \frac{1}{\frac{(2\pi - a)}{2\pi} \times 2\pi R \times A}$$

$$= \frac{w}{28} \times \frac{a}{\frac{a}{2\pi} \times 2\pi R \times A}$$

$\Rightarrow 32(2\pi - a) = 28a \Rightarrow 8(2\pi - a) = 7a$

$\Rightarrow 2\pi \times 8 = 15a \Rightarrow a = \frac{2\pi \times 8}{15} \approx 192°$

(where w = masses of gases, which is equal for both gases)

Thus, we have $\Rightarrow a = 192°$

27. [True] In $p - v$ graph slope of adiabatic = γ (slope of isothermal) or slope of adiabatic > slope of isothermal.

28. [0.30] When bouyant force on (tube + air) system will become equal to weight of tube then tube will start sinking. (Here we can neglect weight of air as compared to weight of tube)

Now, Let volume of air in this case = V_{air}

$F_B = mg$

So, $\delta_w(V_{tube} + V_{air})g = mg$

$\Rightarrow 1\,(5/2.5\text{ cm}^3 + V_{air}) = 5 \Rightarrow 2 + v_{air} = 5$

$V_{air} = 3\text{ cm}^3$

As initial volume of air = 3.3 cm^3

So, $\Delta V = 0.3$cc

So, $X = 0.30$

29. [10] As temperature of air is constant

So, $PV =$ constant

$P_0 3.3 = P_f 3$, P_f is final pressure of air

$\Rightarrow P_f = 1.1P_0 = P_0 + 0.1P_0$

So, $\Delta P = 10^4$ Pa

So, $Y = 10$

30. (c) $v_s > v_t$ and $U_s < U_t$

$1 \times n \times RTnRT$

$$U_n = \frac{1 \times n \times RT}{2} = \frac{nRT}{2}$$

$$v_n = \sqrt{\frac{\gamma RT}{M}} = \sqrt{\frac{\left(1 + \frac{2}{n}\right)RT}{M}}$$

and $v_s > v_t$

31. (b) Heat generated by the load (external device) = 3kW

Total heat generated in 3hr $= 3 \times 3 \times 10^3 \times (3600) = 324 \times 10^5$ W-sec

For the water cooler,

volume = 120 liters = 0.12m^3, density of water is 1000 kg m^{-3}

mass = density × volume $= 0.12 \times 1000 = 120$kg

Specific heat of water is 4.2 kJ kg^{-1} K^{-1}, Initial temperature = 10°C, Final temperature = 30°C

Heat gain

$\Delta Q = ms\Delta T = 120 \times 4200 \times 20$

$= 100.8 \times 10^5$ J

Rate of cooling of cooler = P

Heat absorbed by the cooler = Pt = Total heat generated-heat gain by water

$Pt = 324 \times 10^5 - 100.8 \times 10^5$

$= 223.2 \times 10^5$ J

$P = 223. \times 10^5/(3 \times 3600) = 2067$W

32. (b) For a diatomic gas,

$$C_v = \frac{5}{2}R$$

$$\Delta U_{BA} = nC_v(T_B - T_A)$$

$$= 1 \times \frac{5R}{2}(800 - 400) = 1000R$$

$$\Delta U_{AC} = \Delta Q_{AC} - W_{AC}$$

$$= nC_p(T_A - T_C) - nR(T_A - T_C)$$

$$= nC_v(T_A - T_C)$$

$$1 \times \frac{5R}{2}(400 - 600) = -500R$$

As a result, when we sum up the changes in internal energy in each of these processes, we obtain 500R for the change in internal energy from C to B. Because internal energy change is a point function,

$U_{BC} = -500R$

33. (a) The total heat is conserved

$Q_{supplied} = Q_{absorbed} + Q_{loss}$

$Q_{supplied} = 1$ kW × 1 sec = 1000 J

$Q_{absorbed} = 1000 - 160 = 840$ J

We know that Heat = Power × time

Also Heat gain = $ms\Delta T$

Mass of water = 2kg, Specific heat of water is 4.2 kJ/kg,

$\Delta T = 77 - 27 = 50$°C

$Pt = 2 \times 4200 \times 50 = 420000$

$t = 42 \times 10^4/840 = 500$ sec

1 min = 60 sec

$t = 8$ min 20 sec

34. (b) For ice,

mass = 2kg, Initial Temperature = −20°C, let final temperature = 0°C, specific heat of ice = $s = 0.5$kcal/kg/°C

Heat gain Q_1 (ice at −20°C to ice at 0°C) = ms

$\Delta T = 2 \times 0.5 \times 20 = 20$kcal

Q_2 (ice at 0°C to water at 0°C) = mL_f = $m \times 80$kcal

For water,

mass = 5kg, Initial Temperature = 20°C, final temperature = 0°C, specific heat of water = s = 1kcal/kg/°C

Heat loss Q_3 (water at 20°C to water at 0°C) = $ms\Delta T = 5 \times 1 \times 20 = 100$ kcal

Heat gain = heat loss

$20 + m \times 80 = 100$

$m = 1$kg

Total mass of water = 5 + 1 = 6kg

35. (d) Internal energy of n moles of an ideal gas at temperature T is given by

$$U = n\left(\frac{f}{2}RT\right)$$

where, f = degrees of freedom.

= 5 for O_2 and 3 for Ar

Hence, $U = U_{O_2} + U_{Ar}$

$$= 2\left(\frac{5}{2}RT\right) + 4\left(\frac{3}{2}RT\right) = 11RT$$

36. (d) A is free to move, therefore, heat will be supplied at constant pressure

$\therefore \Delta Q_A = nC_p\Delta T_A$

@MAKE_CBSE_FOR_ALL_EDUNET

B is held fixed, therefore, heat will be supplied at constant volume.

$\therefore \Delta Q_B = nC_v\Delta T_B$ ...(ii)

But $\Delta Q_A = \Delta Q_B$ (given)

$\therefore nC_p\Delta T_A = nC_v\Delta T_B$

$\therefore \Delta T_B = \left(\frac{C_p}{C_v}\right)\Delta T_A$

$= \gamma(\Delta T_A)$ [$\gamma = 1.4$ diatomic]

$(\Delta T_A = 30K) = (1.4)(30\ K)$

$\Delta T_B = 42K$

37. (b) $\gamma_1 = \frac{5}{3}$ means gas is mono-atomic or

$C_{V_1} = \frac{3}{2}R$

$\gamma_2 = \frac{7}{5}$ means gas is diatomic or

$C_{V_2} = \frac{5}{2}R$

C_V (of the mixture) $\frac{n_1C_{V_1} + n_2C_{V_2}}{n_1 + n_2}$

$= \frac{(1)\left(\frac{3}{2}R\right) + (1)\left(\frac{5}{2}\right)R}{1+1} = 2R$

C_p(of the mixture) $= C_V + R = 3R$

$\therefore \gamma_{mixture} = \frac{C_p}{C_V} = \frac{3R}{2R} = 1.5$

38. (b) Heat required to raise the temperature of gas at constant pressure,

$Q = nC_p dT$

$n = 2$moles, $dT = (35 - 30) = 5$

$Q = 10C_p = 70$ cal

$C_p = 70$

Heat required to raise the temperature of gas at constant volume,

$Q' = nC_v\ dT$

$n = 2$moles, $dT = (35\text{-}30) = 5$

$Q' = 10C_V$

For diatomic gas degree of freedom $f = 5$

Also $\frac{C_p}{C_V} = 1 + \frac{2}{f} = 7/5$

$C_v = 5$

$Q' = 10C_V = 50$ cal

39. (b,c,d) Option (a) the graph between (0–100K) appears to be a straight line upto a reasonable approximation.

Option (b) the area under the curve in the temperature range (0 – 100K) is less than in the range (400 – 500K).

Option (c) the graph of C versus T is constant in the temperature range (400–500K)

Option (d) the temperature range (200–300K) specific heat capacity increases with temperature.

40. (d) We know,

$Q = mC_p\Delta t$ for constant pressure process

$Q = mC_v\Delta t$ for constant volume process

Thus, $Q_{lower} = 2 \times \frac{3}{2} \times (700 - T)$

But,

Heat given by lower compartment = Heat gained by upper compartment

$\therefore 2 \times \frac{7}{2} \times (T - 400) = 2 \times \frac{3}{2} \times (700 - T)$

$\therefore T = 490\ K$

41. [675, 3.6×10^6] Vessel is closed. Therefore, $W = 0$

or $Q = \Delta U = nC_v\Delta t$

$\Delta T = \frac{Q}{nC_V} = \frac{\Delta Q}{\left(\frac{pV}{RT}\right)(C_p - R)}$

$= \frac{(Q)(RT)}{pV(C_p - R)}$

Substituting the values, we have

$\Delta T = \frac{(2.49\times10^4)(300)}{(1.6\times10^6)(0.0083)\left(\frac{3}{2}\right)} = 375$ K

$\therefore T_f = \Delta T + T = 675$ K

Further at constant volume

$\frac{p_2}{p_1} = \frac{T_2}{T_1}$

$\therefore p_2 = \frac{T_2}{T_1}p_1 = \left(\frac{675}{300}\right)(1.6\times10^6)$

$= 3.6 \times 10^6$ N/m²

42. [4.54×10^{-3}] Given: $L = 5$m $r = 2 \times 10^{-3}$ m

$S = 420$ J/kg°C

Mass of the bob $m = 100$ kg

Elastic potential energy stored in the wire

$U = \frac{1}{2} \times \frac{F}{A} \times \frac{\Delta L}{L} \times AL$

where $\Delta L = \frac{FL}{AY}$

$\Rightarrow U = \frac{F^2L}{2AY}$

Mass of the wire $M = \rho(\pi r^2 L)$

$\therefore MS\Delta T = \frac{F^2L}{2AY}$ where $F = mg$

Or

$\rho(\pi r^2 L)S\Delta T = \frac{m^2g^2L}{2(\pi r^2)Y}$

$\Rightarrow \Delta T = \frac{m^2g^2}{2\pi^2r^4\rho YS}$

$\therefore \Delta T = \frac{(100)^2 \times (10)^2}{2\pi^2(2\times10^{-3})^4 \times 7860 \times (2.1\times10^{11})(420)}$

$= 4.54 \times 10^{-3}$°C

43. [800, 720] Initially

$P_1V_1 \Rightarrow nR = \frac{10^5 \times 2.4 \times 10^{-3}}{300} = 0.8$

Final $T_2 = \frac{P_2V_2}{nR}$

$P_2 = \frac{Kx}{A} + 10^5 \Rightarrow \frac{8\times10^3 \times 10^{-1}}{8\times10^{-3}} + 10^5$

$= 2 \times 10^5$ N/m²

$V_2 = 8 \times 10^{-4} + 24 \times 10^{-4} = 32 \times 10^{-4}$

$T_2 = 800$ K

$Q = w_{gas} + \Delta U$

$w_{air} = 10^5 \times 10^{-1} \times 8 \times 10^{-3} = 80$ J

$w_{spring} = \frac{1}{2}kx^2 \Rightarrow \frac{1}{2} \times 8000 \times 10^{-2} \Rightarrow 40$

$\Delta U = nC, \Delta T = n \times \frac{3}{2}R \times 500$

$\Rightarrow 0.8 \times \frac{3}{2} \times 500 \Rightarrow 600$ J

$\therefore Q = 80 + 40 + 600$

Total heat supplied +720J

44. [410] Let m be the mass, v be the velocity of the bullet.

Kinetic energy of the bullet just before striking $= \frac{1}{2}mv^2$

After striking this energy gets converted to heat.

Total Heat produced $= Q = \frac{1}{2}mv^2$

25% heat is absorbed

Heat for melting the bullet $Q_1 = (1 - 0.25)$

$Q_1 = 0.75 \times \frac{1}{2}mv^2 = ms\Delta T + mL$

Also, Heat $Q_1 = ms\Delta T + mL$

(s) specific heat of lead, (L) latent heat, melting point of lead = 327°C

$0.75 \times \frac{1}{2}mv^2 = ms\Delta T + mL$

$v^2 \times 0.375 = 0.03 \times (327 - 27) + 6$

$v^2 = 40000 \times 4.2$ J/kg

$v = 410$ m/s

45. In thermal equilibrium, the rate of absorbing heat

$= P =$ rate of losing heat due to radiation

When the power source is turned off, the temperature does not change, thus, the system remains losing heat at the same rate. Therefore, heat lost in time t

@FAKE_OBSERV @RAJ EDUNET

$= Pt$ = required heat loss for complete solidification $= ML$

Where L = latent heat of fusion.

46. Let the final temperature of mixture be x°C

300g of water at 25°C converts to water at x°C

Heat loss $= msdT = 300(25-x)$

100g of ice at 0°C converts to water at 0°C

Heat gain = mL = 100 × 75 cal

water at 0°C converts to water at °C

Heat gain $= msdT = 100(x)$

Heat loss = heat gain

$300(25-x) = 100 \times 75 + 100x$

$x = 0$

final temperature of mixture = 0°C

47. $C_v = \dfrac{n_1 C_{v_1} + n_2 C_{v_2}}{n_1 + n_2}$

$= \dfrac{(1)\left(\frac{3}{2}R\right) + (1)\left(\frac{5}{2}R\right)}{1+1} = 2R$

48. [121] At constant pressure, work done

$W = nR\Delta T = 66$

Internal energy,

$\Delta U = n(C_v)_{mix}\Delta T$

$(C_v)_{mix} = \dfrac{n_1 C_{v_1} + n_2 C_{v_2}}{n_1 + n_2}$

$= \dfrac{2 \times \frac{3}{2}R + 1 \times \frac{5}{2}R}{3}$

$(C_v)_{mix} = \dfrac{11}{6}R$

$\Delta U = \dfrac{11}{6}(nR\Delta T) = \dfrac{11}{6} \times 66 = 121\ J$

49. If the container is suddenly stopped loss in kinetic energy of gas

$= \dfrac{1}{2}(mn)v_0^2$

where n is number of moles of gas.

Suppose ΔT is the fall in temperature of gas,

Then, $n\left(\frac{3}{2}R\Delta T\right) = \dfrac{1}{2}mnv_0^2$

$\Delta T = \dfrac{mv_0^2}{3R}$

50. Since, the temperature and surface area is the same, therefore the energy emitted per second by both spheres is the same. We know that

$Q = mc\Delta T$

$\dfrac{dQ}{dt} = \dfrac{mc\Delta T}{dT}$

Since $\dfrac{dQ}{dt}$ is the same and c is also the same (both copper).

$\therefore m \propto \dfrac{1}{\Delta T}$

Mass of the hollow sphere is less, therefore Temperature change will be more.

$\therefore$ Hollow sphere will cool faster.

51. [9] $\sigma AT^4 = -ms\dfrac{dT}{dt}$

$\int_{200}^{100} \dfrac{dT}{T^4} = \int_0^{t_1} k\,dt$

$\left[\dfrac{.1}{3T^3}\right]_{200}^{100} = kt_1$

$\dfrac{1}{3}\left(\dfrac{1}{100^3} - \dfrac{1}{200^3}\right) = kt_1$

$\left[\dfrac{1}{3T^3}\right]_{200}^{50} = kt_2$

$\dfrac{1}{3}\left(\dfrac{1}{50^3} - \dfrac{1}{200^3}\right) = kt_2$

$\dfrac{t_2}{t_1} = \left(\dfrac{200^3 - 50^3}{200^3 - 100^3}\right)\dfrac{100^3}{50^3} = 9$

@FAKE_CBSE X @RAJ_EDUNET

14 Thermodynamics

Scan for Sol.

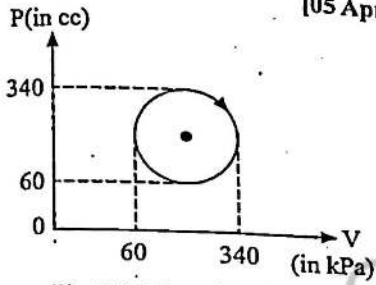
JEE-Main

First Law of Thermodynamics & Work Done, Heat Internal Energy

1. A diatomic gas ($\gamma = 1.4$) does 200 J of work when it is expanded isobarically. The heat given to the gas in the process is: **[1 Feb, 2024 (Shift-II)]**

(a) 850 J (b) 800 J (c) 600 J (d) 700 J

2. The heat absorbed by a system in going through the given cyclic process is: **[05 April, 2024 (Shift-I)]**



(a) 61.6 J (b) 431.2 J (c) 616 J (d) 19.6 J

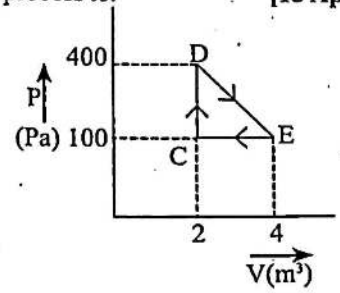
3. A total of 48 J heat is given to one mole of helium kept in a cylinder. The temperature of helium increases by 2°C. The work done by the gas is: **[06 April, 2024 (Shift-II)]**
(Given, $R = 8.3\ J\ K^{-1}mol^{-1}$.)

(a) 72.9 J (b) 24.9 J (c) 48 J (d) 23.1 J

4. 1g of a liquid is converted to vapour at $3 \times 10^5\ Pa$ pressure. If 10% of the heat supplied is used for increasing the volume by 1600 cm^3 during this phase change, then the increase in internal energy in the process will be: **[24 Jan, 2023 (Shift-I)]**

(a) 4320 J (b) 432000 J (c) 4800 J (d) 4.32×10^8 J

5. A thermodynamic system is taken through cyclic process. The total work done in the process is: **[15 Apr, 2023 (Shift-I)]**



(a) 100 J (b) 300 J
(c) Zero (d) 200 J

6. 1 kg of water at 100°C is converted into steam at 100°C by boiling at atmospheric pressure. The volume of water changes from $1.00 \times 10^{-3}\ m^3$ as a liquid to 1.671 m^3 as steam. The change in internal energy of the system during the process will be (Given latent heat of vaporisaiton = 2257 kJ/kg. Atmospheric pressure $= 1 \times 10^5$ Pa) **[11 Apr, 2023 (Shift-I)]**

(a) +2090 kJ (b) −2090 kJ
(c) −2426 kJ (d) +2476 kJ

7. A cylindrical furnace has height (H) and diameter (D) both 1 m. It is maintained at temperature 360 K. The air gets heated inside the furnace at constant pressure Pa and its temperature becomes T = 360 K. The hot air with density ρ rises up a vertical chimney of diameter d = 0.1 m and height h = 9 m above the furnace and exits the chimney (see the figure). As a result, atmospheric air of density $\rho a = 1.2\ kg\ m^{-3}$, pressure Pa and temperature Ta = 300 K enters the furnace. Assume air as an ideal gas, neglect the variations in ρ and T inside the chimney and the furnace. Also ignore the viscous effects. [Given: The acceleration due to gravity g = 10 ms−2 and π = 3.14]. Considering the air flow to be streamline, the steady mass flow rate of air exiting the chimney is____ gm s^{-1}. **[JEE Adv, 2023]**

8. A source supplies heat to a system at the rate of 1000 W. If the system performs work at a rate of 200 W. The rate at which internal energy of the system increases **[6 Apr, 2023 (Shift-I)]**

(a) 1200 W (b) 600 W
(c) 500 W (d) 800 W

9. Given below are two statements:

Statement-I: If heat is added to a system, its temperature must increase.

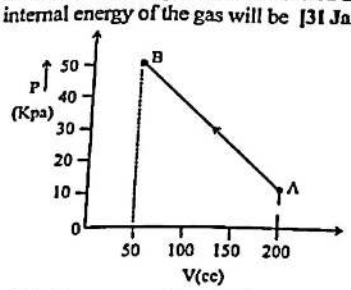
Statement-II: If positive work is done by a system in a thermodynamic process, its volume must increase.

In the light of the above statements, choose the correct answer from the options given below **[8 Apr, 2023 (Shift-I)]**

(a) Statement I is true but Statement II is false
(b) Both Statement I and Statement II are true
(c) Both Statement I and Statement II are false
(d) Statement I is false but Statement II is true

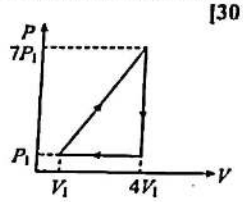
@EAKE CBSE X SAJ EDUCAT

10. The pressure of a gas changes linearly with volume from A to B as shown in figure. If no heat is supplied to or extracted from the gas then change in the internal energy of the gas will be **[31 Jan, 2023 (Shift-I)]**



(a) 6 J (b) Zero (c) –4.5 J (d) 4.5 J

11. In the cyclic process shown in the figure, the work done by the gas in one cycle is **[30 Jan, 2023 (Shift-I)]**



(a) $28P_1V_1$ (b) $14P_1V_1$ (c) $18P_1V_1$ (d) $9P_1V_1$

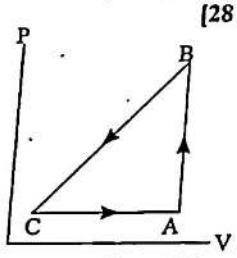
12. Heat is given to an ideal gas in an isothermal process.
A. Internal energy of the gas will decrease.
B. Internal energy of the gas will increase.
C. Internal energy of the gas will not change.
D. The gas will do positive work.
E. The gas will do negative work.
Choose the correct answer from the options given below:
[30 Jan, 2023 (Shift-I)]

(a) A and E only (b) B and D only
(c) C and E only (d) C and D only

13. Given below are two statements. One is labelled as **Assertion A** and the other is labelled as **Reason R.**
Assertion A: If dQ and dW represent the heat supplied to the system and the work done on the system respectively. Then according to the first law of thermodynamics $dQ = dU - dW$.
Reason R: First law of thermodynamics is based on law of conservation of energy.
In the light of the above statements, choose the correct answer from the option given below: **[29 Jan, 2023 (Shift-I)]**

(a) A is correct but R is not correct
(b) A is not correct but R is correct
(c) Both A and R are correct and R is the correct explanation of A
(d) Both A and R are correct but R is not the correct explanation of A

14. A sample of an ideal gas is taken through the cyclic process $ABCA$ as shown in figure. It absorbs, 40 J of heat during the part AB, no heat during BC and rejects 60 J of heat during CA. A work of 50 J is done on the during the part BC. The internal energy of the gas at A is 1560 J. The work donse by the gas during the part CA is:
[28 June, 2022 (Shift-II)]



(a) 20 J (b) 30 J (c) –30 J (d) –60 J

15. A cylinder of fixed capacity of 44.8 litres contains helium gas at standard temperature and pressure. The amount of heat needed to raise the temperature of gas in the cylinder by 20.0°C will be: **[29 June, 2022 (Shift-I)]**
(Given gas constant $R = 8.3\ JK^{-1} - mol^{-1}$)
(a) 249 J (b) 415 J (c) 498 J (d) 830 J

16. A thermally insulated vessel contains an ideal gas of molecular mass M and ratio of specific heats 1.4. Vessel is moving with speed v and is suddenly brought to rest. Assuming no heat is lost to the surrounding and vessel temperature of the gas increases by: **[26 June, 2022 (Shift-I)]**
(R = universal gas constant)

(a) $\frac{Mv^2}{7R}$ (b) $\frac{Mv^2}{5R}$ (c) $2\frac{Mv^2}{7R}$ (d) $7\frac{Mv^2}{5R}$

17. At a certain temperature, the degrees of freedom per molecule for gas is 8. The gas performs 150 J of work when it expands under constant pressure. The amount of heat absorbed by the gas will be _____ J. **[28 July, 2022 (Shift-II)]**

18. A monoatomic gas performs a work of $\frac{Q}{4}$ where Q is the heat supplied to it. The molar heat capacity of the gas will be _____ J during this transformation. Where R is the gas constant. **[24 June, 2022 (Shift-II)]**

19. List I describes thermodynamic processes in four different systems. List II gives the magnitudes (either exactly or as a close approximation) of possible changes in the internal energy of the system due to the process. **[JEE Adv, 2021]**

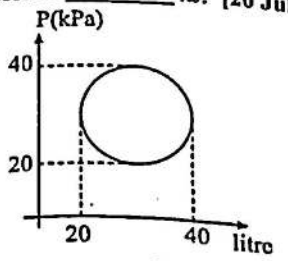
	List-I		List-II
A.	10^{-3} kg of water at 100°C is converted to steam at the same temperature, at a pressure of 10^5 Pa. The volume of the system changes from 10^{-6} m³ to 10^{-3} m³ in the process. Latent heat of water = 2250 kJ/kg.	I.	2 kJ
B.	0.2 moles of a rigid diatomic ideal gas with volume V at temperature 500 K undergoes an isobaric expansion to volume 3 V. Assume $R = 8.0 Jmol^{-1} K^{-1}$.	II.	7 kJ
C.	One mole of a monoatomic ideal gas is compressed adiabatically from volume $V = \frac{1}{3}$ m³ and pressure 2kPa to volume $\frac{V}{8}$.	III.	4 kJ
D.	Three moles of a diatomic ideal gas whose molecules can vibrate, is given 9 kJ of heat and undergoes isobaric expansion.	IV.	5 kJ
		V.	3 kJ

(a) A → V; B → III; C → IV; D → II
(b) A → I; B → III; C → V; D → II
(c) A → IV; B → I; C → V; D → I
(d) A → II; B → III; C → IV; D → V

20. The volume V of a given mass of monoatomic gas changes with temperature T according to the relation $V = kT^{\frac{2}{3}}$. The work done when temperature changes by 90K will be xR. The value of x is _____. **[26 Feb, 2021 (Shift-II)]**
[R = universal gas constant]

@IITJEE_X @RANKBOOSTER

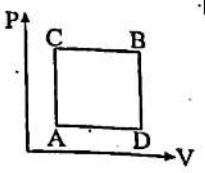
11. In the reported [illegible] absorbed by a system in going through a cyclic process is _____ πJ. **[20 July, 2021 (Shift-I)]**



12. 1 mole of rigid diatomic gas performs a work of $\frac{Q}{5}$ when heat Q is supplied to it. The molar heat capacity of the gas during this transformation is $\frac{xR}{8}$. The value of x is _____.

[R = universal gas constant] **[26 Feb, 2021 (Shift-II)]**

13. A gas can be taken from A to B via two different processes ACB and ADB. When path ACB is used 60 J of heat flows into the system and 30 J of work is done by the system. If path ADB is used work down by the system is 10 J. the heat flow into the system in path ADB is **[9 Jan, 2019 (Shift-I)]**



(a) 40 J (b) 80 J (c) 100 J (d) 20 J

14. Half mole of an ideal monoatomic gas is heated at constant pressure of 1 atm from 20°C to 90°C. Work done by has is close to: (Gas constant $R = 8.31$ J/mol.K) **[10 Jan, 2019 (Shift-II)]**

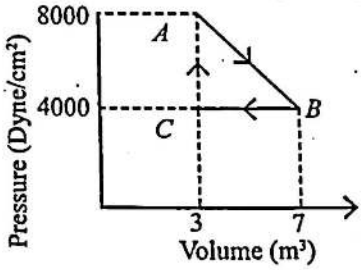
(a) 581 J (b) 291 J (c) 146 J (d) 73 J

Thermodynamics Process

15. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio of $\frac{C_p}{C_v}$ for the gas is: **[27 JAN, 2024 (Shift-II)]**

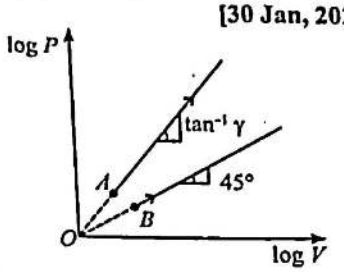
(a) $\frac{5}{3}$ (b) $\frac{3}{2}$ (c) $\frac{7}{5}$ (d) $\frac{9}{7}$

16. A thermodynamic system is taken from an original state A to an intermediate state B by a linear process as shown in the figure. It's volume is then reduced to the original value from B to C by an isobaric process. The total work done by the gas from A to B and B to C would be: **[29 Jan, 2024 (Shift-I)]**



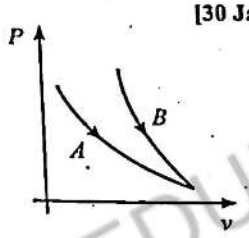
(a) 33800J (b) 2200J (c) 600J (d) 1200J

27. Two thermodynamical process are shown in the figure. The molar heat capacity for process A and B are C_A and C_B. The molar heat capacity at constant pressure and constant volume are represented by C_P and C_V, respectively. Choose the correct statement. **[30 Jan, 2024 (Shift-I)]**



(a) $C_B = \infty, C_A = 0$ (b) $C_A = 0$ and $C_B = \infty$
(c) $C_P > C_V > C_A = C_B$ (d) $C_A > C_P > C_V$

28. Choose the correct statement for processes A & B shown in figure. **[30 Jan, 2024 (Shift-II)]**

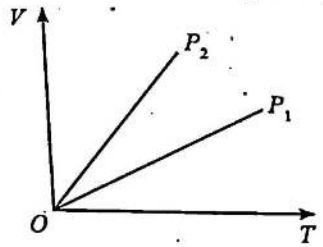


(a) $PV = k$ for process B and $PV = k$ for process A.
(b) $PV = k$ for process B and A.
(c) $\frac{P^{\gamma-1}}{T^{\gamma}} = k$ for process B and $T = k$ for process A.
(d) $\frac{T^{\gamma}}{P^{\gamma-1}}$ k for process A and $PV = k$ for process.

29. If three moles of monoatomic gas $\left(\gamma = \frac{5}{3}\right)$ mixed with two moles of a diatomic gas $\left(\gamma = \frac{7}{5}\right)$ the value of adiabatic exponent γ for the mixture is: **[30 Jan, 2024 (Shift-II)]**

(a) 1.75 (b) 1.40 (c) 1.52 (d) 1.35

30. The given figure represents two isobaric processes for the same mass of an ideal gas, then **[31 Jan, 2024 (Shift-I)]**



(a) $P_2 \geq P_1$ (b) $P_2 > P_1$ (c) $P_1 = P_2$ (d) $P_1 > P_2$

31. The pressure and volume of an ideal gas are related as $PV^{3/2} = K$ (Constant). The work done when the gas is taken from state A (P_1, V_1, T_1) to state B (P_2, V_2, T_2) is: **[1 Feb, 2024 (Shift-I)]**

(a) $2(P_1V_1 - P_2V_2)$ (b) $2(P_2V_2 - P_1V_1)$
(c) $2\left(\sqrt{P_1}V_1 - \sqrt{P_2}V_2\right)$ (d) $2\left(P_2\sqrt{V_2} - P_1\sqrt{V_1}\right)$

@TAKE_CBSE_X @RAJ_EDUNET

32. A sample of gas at temperature T is adiabatically expanded to double its volume. Adiabatic constant for the gas is $\gamma = 3/2$. The work done by the gas in the process is : ($\mu = 1$ mole) **[04 April, 2024 (Shift-II)]**

(a) $RT\left[\sqrt{2}-2\right]$ (b) $RT\left[1-2\sqrt{2}\right]$

(c) $RT\left[2\sqrt{2}-1\right]$ (d) $RT\left[2-\sqrt{2}\right]$

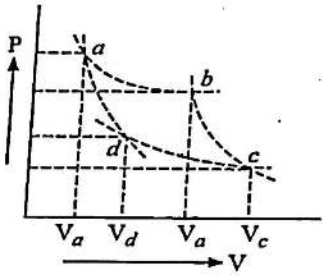
33. During an adiabatic process, if the pressure of a gas is found to be proportional to the cube of its absolute temperature, then the ratio of $\frac{C_P}{C_V}$ for the gas is: **[05 April, 2024 (Shift-II)]**

(a) $\frac{5}{3}$ (b) $\frac{9}{7}$ (c) $\frac{3}{2}$ (d) $\frac{7}{5}$

34. The specific heat at constant pressure of a real gas obeying $PV^2 = RT$ equation is: **[06 April, 2024 (Shift-I)]**

(a) $C_v + R$ (b) $\frac{R}{3} + C_v$ (c) R (d) $C_v + \frac{R}{2V}$

35. Two different adiabatic paths for the same gas intersect two isothermal curves as shown in P-V diagram. The relation between the ratio $\frac{V_a}{V_d}$ and the ratio $\frac{V_b}{V_c}$ is: **[08 April, 2024 (Shift-I)]**



(a) $\frac{V_a}{V_d} = \left(\frac{V_b}{V_c}\right)^{-1}$ (b) $\frac{V_a}{V_d} \neq \frac{V_b}{V_c}$

(c) $\frac{V_a}{V_d} = \frac{V_b}{V_c}$ (d) $\frac{V_a}{V_d} = \left(\frac{V_b}{V_c}\right)^2$

36. A diatomic gas ($\gamma = 1.4$) does 100 J of work in an isobaric expansion. The heat given to the gas is: **[08 April, 2024 (Shift-II)]**

(a) 350 J (b) 490 J (c) 150 J (d) 250 J

37. The volume of an ideal gas ($\gamma = 1.5$) is changed adiabatically from 5 litres to 4 litres. The ratio of initial pressure to final pressure is: **[09 April, 2024 (Shift-I)]**

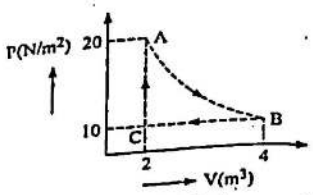
(a) $\frac{4}{5}$ (b) $\frac{16}{25}$ (c) $\frac{8}{5\sqrt{5}}$ (d) $\frac{2}{\sqrt{5}}$

38. A sample of 1 mole gas at temperature T is adiabatically expanded to double its volume. If adiabatic constant for the gas is $\gamma = 3/2$, then the work done by the gas in the process is: **[09 April, 2024 (Shift-I)]**

(a) $RT\left[2-\sqrt{2}\right]$ (b) $\frac{R}{T}\left[2-\sqrt{2}\right]$

(c) $RT\left[2+\sqrt{2}\right]$ (d) $\frac{T}{R}\left[2+\sqrt{2}\right]$

39. A real gas within a closed chamber at 27°C undergoes the cyclic process as shown in figure. The gas obeys $PV^3 = RT$ equation for the path A to B. The net work done in the complete cycle is (assuming $R = 8$J/molK): **[09 April, 2024 (Shift-II)]**



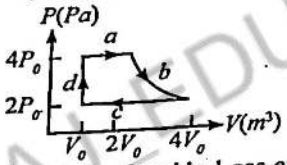
(a) 225 J (b) 205 J (c) 20 J (d) −20 J

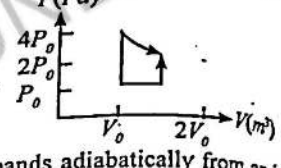
40. A sample of gas at temperature T is adiabatically expanded to double its volume. The work done by the gas in the process is (given, $\gamma = \frac{3}{2}$): **[01 Feb, 2023 (Shift-I)]**

(a) $W = TR\left[\sqrt{2}-2\right]$ (b) $W = \frac{T}{R}\left[\sqrt{2}-2\right]$

(c) $W = \frac{R}{T}\left[2-\sqrt{2}\right]$ (d) $W = RT\left[2-\sqrt{2}\right]$

41. One mole of an ideal gas undergoes two different cyclic processes I and II, as shown in the P–V diagrams below. In cycle I, processes a, b, c and d are isobaric, isothermal, isobaric and isochoric respectively. In cycle II, processes a', b', c' and d' are isothermal, isochoric, isobaric and isochoric, respectively. The total work done during cycle I is W_I and that during cycle II is W_{II}. The ratio W_I/W_{II} is _____. **[JEE Adv, 2023]**





42. One mole of an ideal gas expands adiabatically from an initial state (T_A, V_0) to final state (T_f, $5V_0$). Another mole of the same gas expands isothermally from a different initial state (T_B, V_0) to the same final state (T_f, $5V_0$). The ratio of the specific heats at constant pressure and constant volume of this ideal gas is γ. What is the ratio T_A/T_B? **[JEE Adv, 2023]**

(a) $5^{\gamma-1}$ (b) $5^{1-\gamma}$ (c) 5^{γ} (d) $5^{1/\gamma}$

43. The initial pressure and volume of an ideal gas are P_0 and V_0. The final pressure of the gas when the gas is suddenly compressed to volume $\frac{V_0}{4}$ will be: (Given γ = ratio of specific heats at constant pressure and at constant volume) **[13 Apr, 2023 (Shift-II)]**

(a) $P_0(4)^{\frac{1}{\gamma}}$ (b) $P_0(4)^{\gamma}$ (c) P_0 (d) $4P_0$

44. Consider two containers A and B containing monoatomic gases at the same Pressure (P), Volume (V) and Temperature (T). The gas in A is compressed isothermally to $\frac{1}{8}$ of its original volume while the gas B is compressed adiabatically to $\frac{1}{8}$ of its original volume. The ratio of final pressure of gas in B to that of gas in A is: **[10 Apr, 2023 (Shift-I)]**

(a) 8 (b) $8^{\frac{3}{2}}$ (c) $\frac{1}{8}$ (d) 4

45. A gas is compressed adiabatically, which one of the following statement is NOT true. **[10 Apr, 2023 (Shift-II)]**

(a) There is no heat supplied to the system

(b) The temperature of the gas increases

(c) The change in the internal energy is equal to the work done on the gas.

(d) There is no change in the internal energy

@TAKE_CBSE_X @RAKEDUNET

46. Match List-I with List-II

	List-I		List-II
A.	Isothermal Process	I.	Work done by the gas decreases internal energy
B.	Adiabatic Process	II.	No change in internal energy
C.	Isochoric Process	III.	The heat absorbed goes partly to increase internal energy and partly to do work
D.	Isobaric Process	IV.	No work is done on or by the gas

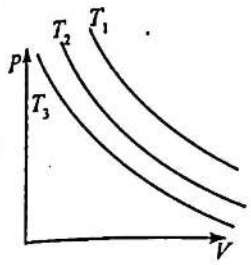
Choose the correct answer from the options given below: **[25 Jan, 2023 (Shift-II)]**

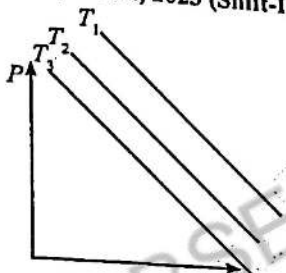
(a) A → II; B → I; C → III; D → IV
(b) A → II; B → I; C → IV; D → III
(c) A → I; B → II; C → IV; D → III
(d) A → I; B → II; C → III; D → IV

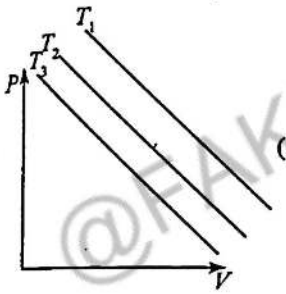
47. The thermodynamic process, in which internal energy of the system remains constant is **[11 Apr, 2023 (Shift-II)]**
(a) Isochoric (b) Isothermal (c) Adiabatic (d) Isobaric

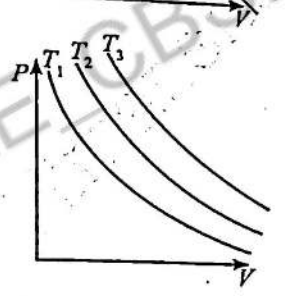
48. Under isothermal condition, the pressure of a gas is given by $P = a^{1/2}$, where a is a constant and V is the volume of the gas. The bulk modulus at constant temperature is equal to **[13 Apr, 2023 (Shift-I)]**
(a) $P/2$ (b) $3P$ (c) $2P$ (d) P

49. In an Isothermal change, the change in pressure and volume of a gas can be represented for three different temperature; $T_3 > T_2 > T_1$ as: **[24 Jan, 2023 (Shift-II)]**

(a)


(b)


(a)


(b)


50. A hypothetical gas expands adiabatically such that its volume changes from 08 litres to 27 litres. If the ratio of final pressure of the gas to initial pressure of the gas is $\frac{16}{81}$. Then the ratio of $\frac{C_P}{C_V}$ will be. **[31 Jan, 2023 (Shift-II)]**

(a) $\frac{4}{3}$ (b) $\frac{3}{1}$ (c) $\frac{1}{2}$ (d) $\frac{3}{2}$

51. A monoatomic gas at pressure P and volume V is suddenly compressed to one eighth of its original volume. The final pressure at constant entropy will be: **[26 July, 2022 (Shift-I)]**
(a) P (b) 8P (c) 32P (d) 64P

52. A bubble has surface tension S. The ideal gas inside the bubble has ratio of specific heats $\gamma = \frac{5}{3}$. The bubble is exposed to the atmosphere and it always retains its spherical shape. When the atmospheric pressure is P_{a1}, the radius of the bubble is found to be r_1 and the temperature of the enclosed gas is T_1. When the atmospheric pressure is P_{a2}, the radius of the bubble and the temperature of the enclosed gas are r_2 and T_2, respectively. **[JEE Advance 2022]**
Which of the following statement(s) is(are) correct?

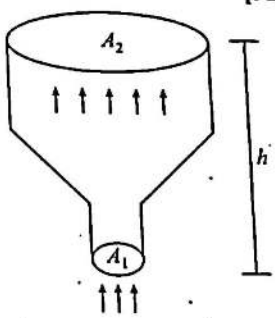
(a) If the surface of the bubble is a perfect heat insulator, then
$$\left(\frac{r_1}{r_2}\right)^3 = \frac{P_{a_2} + \frac{2S}{r_2}}{P_{a_1} + \frac{2S}{r_1}}$$

(b) If the surface of the bubble is a perfect heat insulator, then the total internal energy of the bubble including its surface energy does not change with the external atmospheric pressure.

(c) If the surface of the bubble is a perfect heat conductor and the change in atmospheric temperature is negligible, then
$$\left(\frac{r_1}{r_2}\right)^3 = \frac{P_{a2} + \frac{4S}{r_2}}{P_{a1} + \frac{4S}{r_1}}.$$

(d) If the surface of the bubble is a perfect heat insulator, then
$$\left(\frac{T_2}{T_1}\right)^{\frac{5}{2}} = \frac{P_{a_2} + \frac{4S}{r_2}}{P_{a_1} + \frac{4S}{r_1}}.$$

53. An ideal gas of density r = 0.2 kg m^{-3} enters a chimney of height h at the rate of a = 0.8 kg s^{-1} from its lower end, and escapes through the upper end as shown in the figure. The cross-sectional area of the lower end is $A_1 = 0.1$ m^{-2} and $A_2 = 0.4$ m^{-2} the upper end is . The pressure and the temperature of the gas at the lower end are 600 Pa and 300K respectively, while its temperature at the upper end is 150K. The chimney is heat insulated so that the gas undergoes adiabatic expansion. Take $g = 10$ ms^{-2} and the ratio of specific heats of the gas g = 2. Ignore atmospheric pressure. **[JEE Advance 2022]**



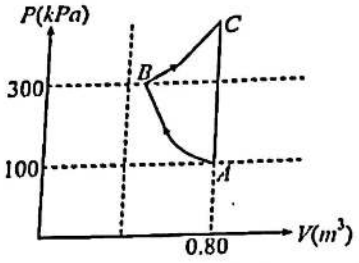
Which of the following statement(s) is (are) correct?

(a) The pressure of the gas at the upper end of the chimney is 300Pa.
(b) The velocity of the gas at the lower end of the chimney is 40 ms^{-1} and at the upper end is 20 ms^{-1}.
(c) The height of the chimney is 590m.
(d) The density of the gas at the upper end is 0.05 kg m^{-3}.

@FAKE_CBSE_EXAM_EDUNET

54. In the given $P-V$ diagram, a monoatomic gas $\left(\gamma=\frac{5}{3}\right)$ is first compressed adiabatically from state A to state B. Then it expands isothermally from state B to state C.

[Given: $\left(\frac{1}{3}\right)^{0.6}$ 0.5, in 2 = 0.7]. **[JEE Advance 2022]**



Which of the following statement(s) is(are) correct?

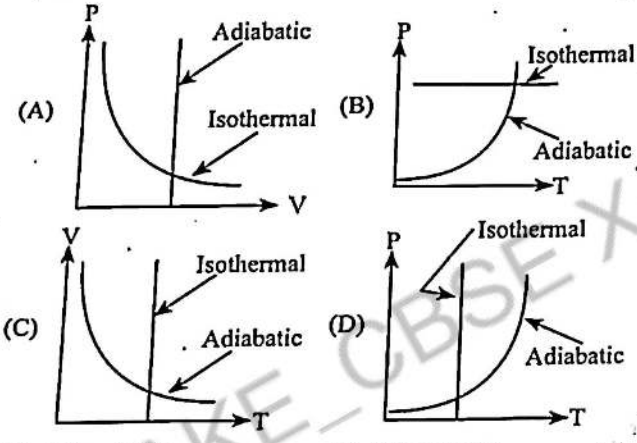
(a) The magnitude of the total work done in the process $A \rightarrow B \rightarrow C$ is 144 kJ.

(b) The magnitude of the work done in the process $B \rightarrow C$ is 84 kJ.

(c) The magnitude of the work done in the process $A \rightarrow B$ is 60 kJ.

(d) The magnitude of the work done in the process $C \rightarrow A$ is zero.

55. Which one is the correct option for the two different thermodynamic processes? **[17 March, 2021 (Shift-II)]**



(a) (C) and (A) (b) (B) and (C)

(c) (C) and (D) (d) (A) only

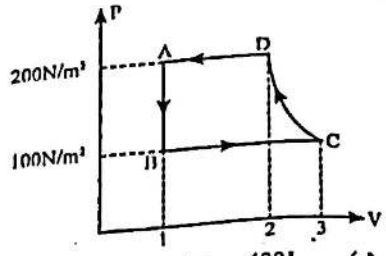
56. The temperature of 3.00 mol of an ideal diatomic gas is increased by 40.0°C without changing the pressure of the gas. The molecules in the gas rotate but do not oscillate. If the ratio of change in internal energy of the gas to the amount of work done by the gas is $\frac{x}{10}$. Then the value of x (round off to the nearest integer) is _____.
(Given $R = 8.31$ J mol^{-1} K^{-1}) **[1 Sept, 2021 (Shift-II)]**

57. The amount of heat needed to raise the temperature of 4 moles of a rigid diatomic gas from 0°C to 50°C when no work is done is _____. (R is the universal gas constant)

[20 July, 2021 (Shift-I)]

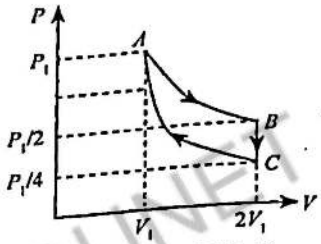
(a) 175 R (b) 750 R (c) 250 R (d) 500 R

58. The P-V diagram of a diatomic ideal gas system going under cyclic process as shown in figure. The work done during an adiabatic process CD is (use $\gamma = 14$): **[18 March, 2021 (Shift-I)]**



(a) −500J (b) 400J (c) −400J (d) 200J

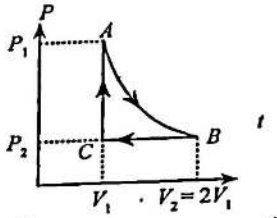
59. If one mole of an ideal gas at (P_1, V_1) is allowed to expand reversibly and isothermally (A to B) its pressure is reduced to one-half of the original pressure (see figure). This is followed by a constant volume cooling till its pressure is reduced to one-fourth of the initial value ($B \rightarrow C$). Then it is restored to its initial state by a reversible adiabatic compression (C to A). The net work done by the gas is equal to: **[24 Feb, 2021 (Shift-I)]**



(a) 0 (b) $RT\ln 2$

(c) $RT\left(\ln 2 - \frac{1}{2(\gamma-1)}\right)$ (d) $-\frac{RT}{2(\gamma-1)}$

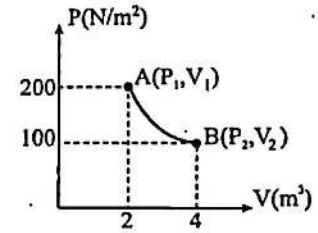
60. n mole of perfect gas undergoes a cyclic process $ABCA$ (see figure) consisting of the following processes.
$A \rightarrow B$: Isothermal expansion at temperature T so that the volume is doubled from V_1 to $V_2 = 2V_1$ and Pressure changes from P_1 to P_2.
$B \rightarrow C$: Isobaric compression at pressure P_2 to initial volume V_1.
$C \rightarrow A$: Isobaric change leading to change of pressure from P_2 to P_1.
Total work done in the complete cycle $ABCA$ is:
[24 Feb, 2021 (Shift-I)]



(a) $nRT\left(\ln 2 + \frac{1}{2}\right)$ (b) $nRT\left(\ln 2 - \frac{1}{2}\right)$

(c) 0 (d) $nRT\ln 2$

61. One mole of an ideal gas at 27°C is taken from A to B as shown in the given PV indicator diagram. The work done by the system will be _____ $\times 10^{-1}$J. **[20 July, 2021 (Shift-II)]**



[Given: $R = 8.3$J/mole K, $\ell n 2 = 0.6931$]
(Round off to the nearest integer)

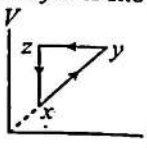
@TAKE_CBSE_X @RAJEDUNET

62. In a certain thermodynamical process, the pressure of a gas depends on its volume as kV^3. The work done when the temperature changes from 100°C to 300°C will be _____ nR, where n denotes numbers of moles of a gas. **[25 Feb, 2021 (Shift-I)]**

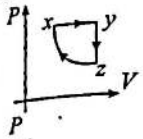
63. Consider one mole of helium gas enclosed in a container at initial pressure P_1 and volume V_1. It expands isothermally to volume $4V_1$. After this, the gas expands adiabatically and its volume becomes $32V_1$. The work done by the gas during isothermal and adiabatic expansion processes are W_{iso} and W_{adia}, respectively. If the ratio $\frac{W_{iso}}{W_{adia}} = f \ln 2$, then f is _____. **[JEE Advance 2020]**

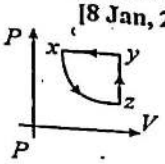
64. A spherical bubble inside water has radius R. Take the pressure inside the bubble and the water pressure to be p_0. The bubble now gets compressed radially in an adiabatic manner so that its radius becomes $(R-a)$. For $a << R$ the magnitude of the work done in the process is given by $(4\pi p_0 R a^2)X$, where X is a constant and $\gamma = C_p/C_v = 41/30$. The value of X is **[JEE Advance 2020]**

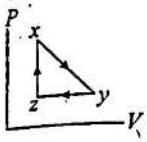
65. A thermodynamic cycle $xyzx$ is shown on a V-T diagram.

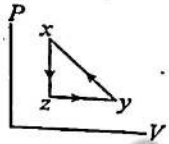


The P-V diagram that best describes this cycle is: (Diagrams are schematic and not to scale) **[8 Jan, 2020 (Shift-I)]**

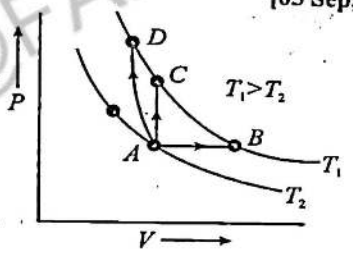
(a) 

(b) 

(c) 

(d) 

66. Three different processes that can occur in an ideal monoatomic gas are shown in the P vs V diagram. The paths are labelled as $A \to B$, $A \to C$ and $A \to D$. The change in internal energies during these process are taken as E_{AB}, E_{AC} and E_{AD} and the work done as W_{AB}, W_{AC} and W_{AD}.
The correct relation between these parameters are **[05 Sep, 2020 (Shift-I)]**



(a) $E_{AB} < E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} > W_{AD}$
(b) $E_{AB} = E_{AC} = E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} > 0$
(c) $E_{AB} > E_{AC} > E_{AD}$, $W_{AB} < W_{AC} < W_{AD}$
(d) $E_{AB} = E_{AC} = E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} < 0$

67. In an adiabatic process, the density of a diatomic gas becomes 32 times its initial value. The final pressure of the gas is found to be n times the initial pressure. The value of n is **[05 Sep, 2020 (Shift-II)]**

(a) 128 (b) 32 (c) $\frac{1}{32}$ (d) 326

68. A litre of dry air at STP expands adiabatically to a volume of 3 litres. If $\gamma = 1.40$, the work done by air is:
$(3^{1.4} = 4.6555)$ [Take air to be an ideal gas] **[7 Jan, 2020 (Shift-I)]**

(a) 90.5 J (b) 48 J (c) 60.7 J (d) 100.8 J

69. Under an adiabatic process, the volume of an ideal gas gets doubled. Consequently the mean collision time between the gas molecules changes from τ_1 to τ_2. If for $\frac{C_p}{C_v} = \gamma$ for the gas then a good estimate for $\frac{\tau_2}{\tau_1}$ is given by: **[7 Jan, 2020 (Shift-II)]**

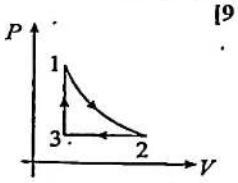
(a) $\left(\frac{1}{2}\right)^{\gamma}$ (b) $2^{\frac{1+\gamma}{2}}$ (c) $\frac{1}{2}$ (d) $\left(\frac{1}{2}\right)^{\frac{\gamma+1}{2}}$

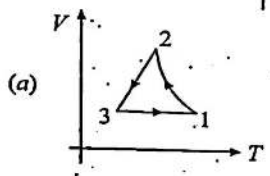
70. Match the thermodynamics processes taking place in a system with the correct conditions. In the table: ΔQ is the heat supplied, ΔW is the work done and ΔU is change in internal energy of the system. Match the following: **[4 Sep, 2020 (Shift-II)]**

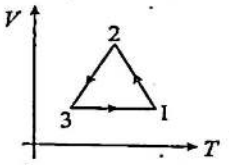
Process		Condition	
A.	Adiabatic	I.	$\Delta W = 0$
B.	Isothermal	II.	$\Delta Q = 0$
C.	Isochoric	III.	$\Delta U \neq 0, \Delta W \neq O, \Delta Q \neq 0$
D.	Isobaric	IV.	$\Delta U = 0$

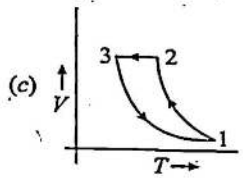
(a) A → II; B → IV; C → I; D → III
(b) A → I; B → I; C → II; D → III
(c) A → I; B → II; C → IV; D → IV
(d) A → II; B → I; C → IV; D → III

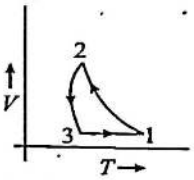
71. Which of the following is an equivalent cyclic process corresponding to the thermodynamic cyclic given in the figure? Where, 1 → 2 is adiabatic. (Graphs are schematic and are not to scale) **[9 Jan, 2020 (Shift-I)]**



(a) 

(b) 

(c) 

(d) 

72. A balloon filled with helium (32°C and 1.7 atm.) bursts. Immediately afterwards the expansion of helium can be considered as: **[03 Sep, 2020 (Shift-I)]**

(a) Irreversible adiabatic (b) Reversible isothermal
(c) Reversible adiabatic (d) Irreversible isothermal

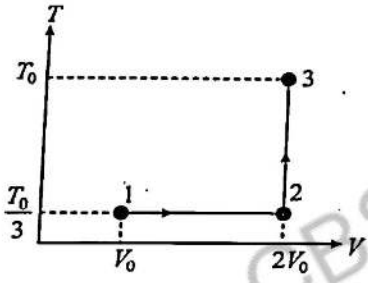
73. Starting at temperature 300 K, one mole of an ideal diatomic gas ($\gamma = 1.4$) is first compressed adiabatically from volume V_1 to $V_2 = V_1/16$. It is then allowed to expand isobarically to volume $2V_2$. If all the processes are the quasi-static then the final temperature of the gas (in °K) is (to the nearest integer) _____. **[9 Jan, 2020 (Shift-II)]**

@FAKE_JOSE_X_@R_FRIENDS

74. An engine takes in 5 moles of air at 20°C and 1 atm, and compresses it adiabatically to 1/10th of the original volume. Assuming air to be a diatomic ideal gas made up of rigid molecules, the change in its internal energy during this process comes out to be X kJ. The value of X to the nearest integer is **[2 Sep, 2020 (Shift-I)]**

75. If the process on one mole of monotomic ideal gas is as shown in the TV-diagram with $P_0V_0 = \frac{1}{3}RT_0$, the correct match is **[JEE Advance 2019]**

A.	Work done by the system in process energy $1 \to 2 \to 3$	I.	$\frac{1}{3}RT_0 \ln 2$
B.	Change in internal in process $1 \to 2 \to 3$	II.	$\frac{1}{3}RT_0$
C.	Heat absorbed by the system in process $1 \to 2 \to 3$	III.	RT_0
D.	Heat absorbed by the system in process $1 \to 2$	IV.	$\frac{4}{3}RT_0$
		V.	$\frac{1}{3}RT_0(3+\ln_2)$
		VI.	$\frac{5}{6}RT_0$



(a) A → IV; B → V; C → II; D → VI
(b) A → I; B → III; C → V; D → IV
(c) A → I; B → V; C → II; D → V
(d) A → I; B → III; C → V; D → I

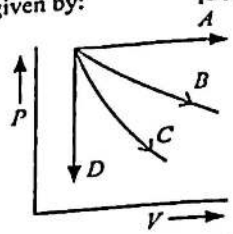
76. A thermally insulated vessel contains 150g of water at 0°C. Then the air from the vessel is pumped out adiabatically. A fraction of water turns into ice and the rest evaporates at 0°C itself. The mass of evaporated water will be closes to:
(Latent heat of vaporization of water = 2.10×10^6 J kg^{-1} and Latent heat of Fusion of water = 3.36×10^5 J kg^{-1}) **[8 April, 2019 (Shift-I)]**
(a) 130 g (b) 35 g (c) 20 g (d) 150 g

77. n-moles of an ideal gas with constant volume heat capacity C_v undergo an isobaric expansion by certain volume. The ratio of the work done in the process, to the heat supplied is **[10 April, 2019 (Shift-I)]**

(a) $\frac{4nR}{C_v - nR}$ (b) $\frac{nR}{C_v - nR}$ (c) $\frac{nR}{C_v + nR}$ (d) $\frac{4nR}{C_v + nR}$

78. A rigid diatomic ideal gas undergoes an adiabatic process at room temperature. The rational between temperature and volume for the process is TV^x = constant, then x is: **[11 Jan, 2019 (Shift-I)]**
(a) 3/5 (b) 2/5 (c) 2/3 (d) 5/3

79. The given diagram shows four processes i.e., isochoric, isobaric, isothermal and adiabatic. The correct assignment of the processes in the same order is given by: **[8 April, 2019 (Shift-II)]**



(a) ADCB (b) ADBC (c) DACB (d) DABC

Second Law of Thermodynamics

80. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.
Assertion A: Efficiency of a reversible heat engine will be higher at -273°C temperature of cold reservoir.
Reason R: The efficiency of a Carnot's engine depends not only on the temperature of cold reservoir but it depends on the temperature of hot reservoir too and is given as $\eta = \left(1 - \frac{T_2}{T_1}\right)$.
In the light of the above statements, choose the correct answer from the options given below: **[30 Jan, 2023 (Shift-II)]**
(a) A is true but R is false
(b) Both A and R are true but R is not the correct explanation of A
(c) A is false but R is true
(d) Both A and R are true and R is the correct explanation of A

81. Read the following statements: **[27 July, 2022 (Shift-I)]**
(A) When small temperature difference between a liquid and its surrounding is doubled the rate of loss of heat of the liquid becomes twice.
(B) Two bodies P and Q having equal surface areas are maintained at temperature 10°C and 20°C. The thermal radiation emitted in a given time by P and Q are in the ratio 1:1.15
(C) A carnot Engine working between 100K and 400K has an efficiency of 75%
(D) When small temperature difference between a liquid and its surrounding is quadrupled, the rate of loss of heat of the liquid becomes twice.
Choose the correct answer from the options given below:
(a) A, B, C only (b) A, B only
(c) A, C only (d) B, C, D only

82. Let η_1 is the efficiency of an engine at $T_1 = 447$°C and $T_2 = 147$°C while η_2 is the efficiency at $T_1 = 947$°C and $T_2 = 47$°C. The ratio η_1/η_2 will be: **[25 July, 2022 (Shift-II)]**
(a) 0.41 (b) 0.56 (c) 0.73 (d) 0.70

83. A steam engine intakes 50g of steam at 100°C per minute and cools it down to 20°C. If latent heat of vaporization of steam is 540 cal g^{-1}, then the heat rejected by the steam engine per minute is _____ 10^3 cal. **[25 June, 2022 (Shift-I)]**

84. A heat engine operates with the could reservoir at temperature 327 K. The minimum temperature of the hot reservoir, if the heat engine takes 300J heat from the hot reservoir and delivers 180 J heat to the cold reservoir per cycle, is _____ K. **[26 June, 2022 (Shift-II)]**

CLEAR CBSE X @ UNEDUNET

85. 300 cal. of heat is given to a heat engine and it rejects 225 cal. of heat. If source temperature is 227°C, then the temperature of sink will be _____ °C. [29 June, 2022 (Shift-I)]

86. A reversible engine has an efficiency of 1/4. If the temperature of the sink is reduced by 58°C, its efficiency becomes double. Calculate the temperature of the sink: [31 Aug, 2021 (Shift-I)]
(a) 280°C (b) 382°C (c) 180.4°C (d) 174°C

87. The entropy of any system is given by $S = \alpha^2\beta\, \ell n\left[\frac{\mu kR}{J\beta^2}+3\right]$

Where α and β are the constants. μ, J, k and R no. of moles, mechanical equivalent of heat, Boltzmann constant and gas constant respectively. [Take $S = \frac{dQ}{T}$] [20 July, 2021 (Shift-I)]

Choose the incorrect option from the following:
(a) S, β, k and μ R have the same dimensions
(b) α and k have the same dimensions
(c) S and α have different dimensions
(d) α and J have the same dimensions

88. An ideal gas in a cylinder is separated by a piston in such a way that the entropy of one part is S_1 and that of the other part is S_2. Given that $S_1 > S_2$. If the piston is removed then the total entropy of the system will be: [18 March, 2021 (Shift-II)]
(a) $S_1 - S_2$ (b) $\frac{S_1}{S_2}$ (c) $S_1 \times S_2$ (d) $S_1 + S_2$

89. A heat engine has an efficiency of $\frac{1}{6}$. When the temperature of sink is reduced by 62°C, its efficiency get doubled. The temperature of the source is: [25 July, 2021 (Shift-II)]
(a) 124°C (b) 99°C (c) 37°C (d) 62°C

90. A heat engine operates between a cold reservoir at temperature T_2 = 400 K and a hot reservoir at temperature T_1. It takes 300 J of heat from the hot reservoir and delivers 240 J of heat to the cold reservoir in a cycle. The minimum temperature of the hot reservoir has to be _____K. [27 Aug, 2021 (Shift-II)]

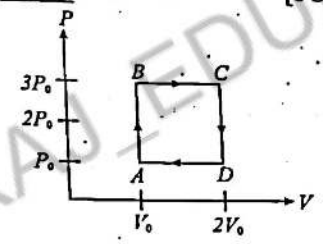
91. A reversible heat engine converts one-fourth of the heat input into work. When the temperature of the sink is reduced by 52 K, its efficiency is doubled. The temperature in Kelvin of the source will be_____ [25 Feb, 2021 (Shift-II)]

92. A refrigerator consumes an average 35 W power to operate between temperature –10°C to 25°C. If there is no loss of energy then how much average heat per second does it transfer? [26 Aug, 2021 (Shift-II)]
(a) 350 J/s (b) 298 J/s (c) 35 J/s (d) 263 J/s

93. A heat engine is involved with exchange of heat of 1915 J, –40 J, +125 J and –QJ, during on cycle achieving and efficiency of 50.0%. The value of Q is: [2 Sep, 2020 (Shift-II)]
(a) 40 J (b) 640 J (c) 400 J (d) 980 J

94. If minimum possible work is done by a refrigerator in converting 100 grams of water at 0°C to ice, how much heat (in calories) is released to the surroundings at temperature 27°C (Latent heat of ice = 80 Cal/gram) to the nearest integer? [3 Sep, 2020 (Shift-II)]

95. An engine operates by taking a monoatomic ideal gas through the cycle shown in the figure. The percentage efficiency of the engine is close to _____. [6 Sep, 2020 (Shift-II)]



@FAKE_CODEX @RAJ_EDUCATE

JEE-Advanced

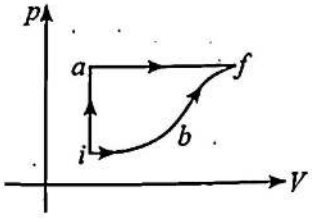
Work

Multiple Correct

1. During the melting of a slab of ice at 273 K at atmospheric pressure [IIT-JEE 1998]
(a) positive work is done by the ice-water system on the atmosphere
(b) positive work is done on the ice-water system by the atmosphere
(c) the internal energy of the ice-water increases
(d) the internal energy of the ice-water system decreases

Numerical Types/Integer Types

2. A thermodynamic system is taken from an initial state i with internal energy u_i = 100 J to the final state f along two different paths iaf and ibf, as schematically shown in the figure.

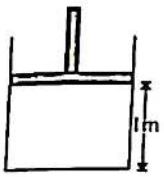


The work done by the system along the paths af, ib and bf are W_{af} = 200 J, W_{ib} = 50 J and W_{bf} = 100 J respectively. The heat supplied to the system along the path iaf, ib and bf are Q_{iaf}, Q_{ib} and Q_{bf} respectively. If the internal energy of the system in the state b is U_b = 200 J and Q_{iaf} = 500 J, the ratio Q_{bf}/Q_{ib} is [C-39.68, W-50.61, UA-9.7(JEE Adv. 2014)]

3. Calculate the work done when one mole of a perfect gas is compressed adiabatically. The initial pressure and volume of the gas are 10^5 N/m² and 6 L respectively. The final volume of the gas is 2 L molar specific heat of the gas at constant volume is 3R/2. [IIT-JEE 1982]

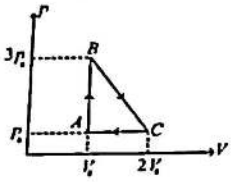
Subjective

4. The piston cylinder arrangement shown contains a diatomic gas at temperature 300 K. The cross-sectional area of the cylinder is 1m^2. Initially the height of the piston above the base of the cylinder is 1m^2. The temperature is now raised to 400K at constant pressure. Find the new height of the piston above the base of the cylinder.



If the piston is now brought back to its original height without any heat loss, find the new equilibrium temperature of the gas. You can leave the answer in fraction. **(IIT-JEE 2004)**

5. One mole of an ideal monoatomic gas is taken round the cyclic process $ABCA$ as shown in figure. **(IIT-JEE 1998)**



Calculate

(*a*) the work done by the gas.

(*b*) the heat rejected by the gas in the path CA and the heat absorbed by the gas in the path AB.

(*c*) the net heat absorbed by the gas in the path BC.

(*d*) the maximum temperature attained by the gas during the cycle.

First Law of Thermodynamics

Match the Column

6. List-I describes thermodynamic processes in four different systems. List-II gives the magnitudes (either exactly or as a close approximation) of possible changes in the internal energy of the system due to the process.

C-28.64 W-29.47 UA-41.88 (JEE Adv. 2022)

	List-I	List-II	
A.	10^{-3} kg of water at 100°C is converted to steam at the same temperature, at a pressure of 10^5 Pa. The volume of the system changes from 10^{-6} m³ to 10^{-3} m³ in the process. Latent heat of water = 2250 kJ/kg.	I.	2 kJ
B.	0.2 moles of a rigid diatomic ideal gas with volume V at temperature 500 K undergoes an isobaric expansion to volume 3 V. Assume $R = 8.0 J\ mol^{-1} K^{-1}$.	II.	7 kJ
C.	On mole of a monoatomic ideal gas is compressed adiabatically from volume $V = \frac{1}{3}$ m³ and pressure 2kPa to volume $\frac{V}{8}$.	III.	4 kJ
D.	Three moles of a diatomic ideal gas whose molecules can vibrate, is given 9 kJ of heat and undergoes isobaric expansion.	IV.	5 kJ
		V.	3 kJ

(*a*) A → V; B → III; C → IV; D → II

(*b*) A → I; B → III; C → V; D → II

(*c*) A → IV; B → I; C → V; D → I

(*d*) A → II; B → III; C → IV; D → V

Thermodynamic Process

Single Correct

7. The thermodynamic process, in which internal energy of the system remains constant is **C-29.88 W-25.05 UA-45.07 (JEE Adv. 2023)**

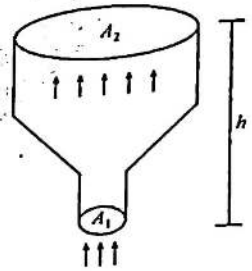
(*a*) Isochoric (*b*) Isothermal (*c*) Adiabatic (*d*) Isobaric

8. One mole of an ideal gas expands adiabatically from an initial state (T_A, V_0) to final state $(T_f, 5V_0)$. Another mole of the same gas expands isothermally from a different initial state (T_B, V_0) to the same final state $(T_f, 5V_0)$. The ratio of the specific heats at constant pressure and constant volume of this ideal gas is γ. What is the ratio T_A/T_B?

C-38 W-24.42 UA-37.59 (JEE Adv. 2023)

(*a*) $5^{\gamma-1}$ (*b*) $5^{1-\gamma}$ (*c*) 5γ (*d*) $5^{1-\gamma}$

9. An ideal gas of density $\rho = 0.2$ kg m^{-3} enters a chimney of height h at a rate of $\alpha = 0.8$ kg s^{-3} from its lower end, and escapes through the upper end as shown in the figure. The cross-sectional area of the lower end is $A_1 = 0.1$ m² and the upper end is $A_2 = 0.4$ m². The pressure and the temperature of the gas at the lower end are 600 Pa and 300K respectively, while its temperature at the upper end is 150K. The chimney is heat insulated so that the gas undergoes adiabatic expansion. Take $g = 10$ ms^{-2} and the ratio of specific heats of the gas $\gamma = 2$. Ignore atmospheric pressure.



C-4.11 W-28.92 UA-66.97 (JEE Adv. 2021)

Which of the following statement(s) is (are) correct?

(*a*) The pressure of the gas at the upper end of the chimney is 300Pa

(*b*) The velocity of the gas at the lower end of the chimney is 40 ms^{-1} and at the upper end is 20 ms^{-1}.

(*c*) The height of the chimney is 590m.

(*d*) The density of the gas at the upper end is 0.05 kg m^{-3}.

10. Two moles of ideal helium gas are in a rubber balloon at 30°C. The balloon is fully expandable and can be assumed to require no energy in its expansion. The temperature of the gas in the balloon is slowly changed to 35°C. The amount of heat required in raising the temperature is nearly (take = 8.31 J/mol – K). **(IIT-JEE 2011)**

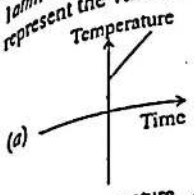
(*a*) 62J (*b*) 104J (*c*) 124J (*d*) 208J

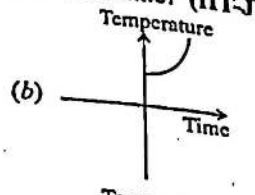
11. An ideal gas is expanding such that pT^2 constant. The coefficient of volume expansion of the gas is **(IIT-JEE 2009)**

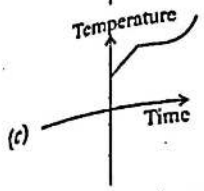
(*a*) $\frac{1}{T}$ (*b*) $\frac{2}{T}$ (*c*) $\frac{3}{T}$ (*d*) $\frac{4}{T}$

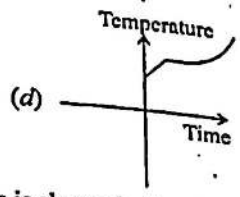
@RAY EDUCATION

12. Liquid oxygen at 50K is heated to 300K at constant pressure of 1atm. The rate of heating is constant. Which of the following graphs represent the variation of temperature with time? **(IIT-JEE 2004)**

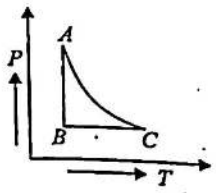
(a) 

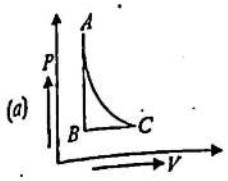
(b) 

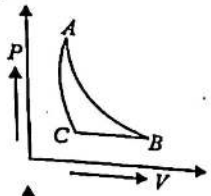
(c) 

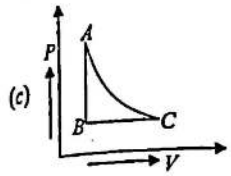
(d) 

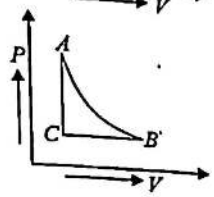
13. The p-T diagram for an ideal gas is shown in the figure, where AC is an adiabatic process, find the corresponding p-V diagram **(IIT-JEE 2003)**



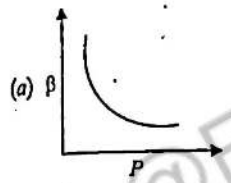
(a) 

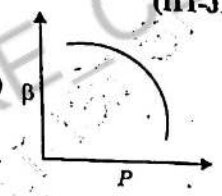
(b) 

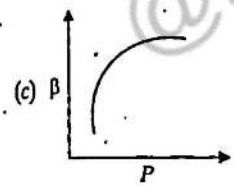
(c) 

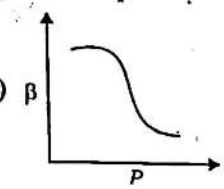
(d) 

14. Which of the following graphs correctly represent the variation of $\beta = -\frac{dV/dp}{V}$ with p for an ideal gas at constant temperature? **(IIT-JEE 2002)**

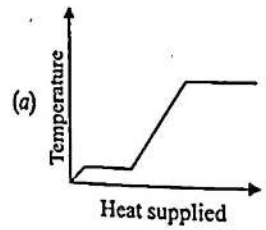
(a) 

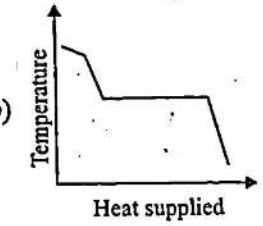
(b) 

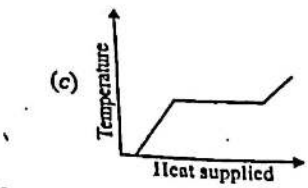
(c) 

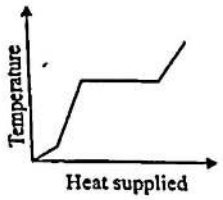
(d) 

15. A block of ice at $-10°C$ is slowly heated and converted to steam at 100°C. Which of the following curves represents the phenomena qualitatively? **(IIT-JEE 2000)**

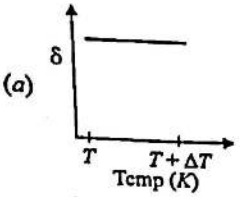
(a) 

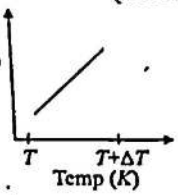
(b) 

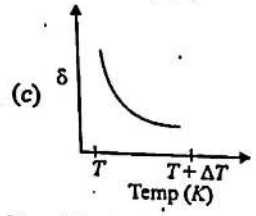
(c) 

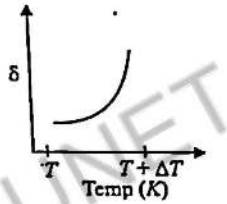
(d) 

16. An ideal gas is initially at temperature T and volume V. Its volume is increased by V due to an increase in temperature ΔT, pressure remaining constant. The quantity $\delta = \frac{\Delta V}{V\Delta T}$ varies with temperature as **(IIT-JEE 2000)**

(a) 

(b) 

(c) 

(d) 

17. Two identical containers A and B with frictionless pistons contain the same ideal gas at the same temperature and the same volume V. The mass of the gas in A is m_A and that in B is m_B. The gas in each cylinder is now allowed to expand isothermally to the same final volume $2V$. The changes in the pressure in A and B are found to be Δp and $1.5\,\Delta p$ respectively. Then **(IIT-JEE 1998)**

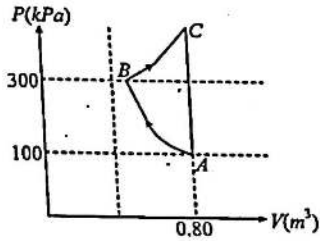
(a) $4m_A = 9m_B$ (b) $2m_A = 3m_B$

(c) $3m_A = 2m_B$ (d) $9m_A = 4m_B$

Multiple Correct

18. In the given $P - V$ diagram, a monoatomic gas $\left(\gamma = \frac{5}{3}\right)$ is first compressed adiabatically from state A to state B. Then it expands isothermally from state B to state C.

[Given: $\left(\frac{1}{3}\right)^{0.6} 0.5$, $\ln 2 = 0.7$]. **(JEE Adv. 2022)**



Which of the following statement(s) is(are) correct?

(a) The magnitude of the total work done in the process $A \to B \to C$ is 144 kJ.

(b) The magnitude of the work done in the process $B \to C$ is 84 kJ.

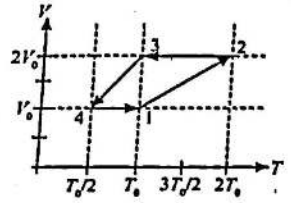
(c) The magnitude of the work done in the process $A \to B$ is 60 kJ.

(d) The magnitude of the work done in the process $C \to A$ is zero.

@FAKE CBSE X @RAJ EDUNET

19. One mole of a monoatomic ideal gas goes through a thermodynamic cycle, as shown in the volume versus temperature ($V-T$) diagram. The correct statement(s) is/are: [R is the gas constant]

C-19 W-40 UA-27 PC-14 (JEE Adv. 2019)



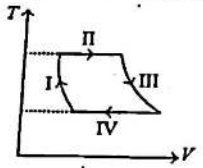
(*a*) Work done in this thermodynamic cycle ($1 \to 2 \to 3 \to 4 \to 1$) is $|W| = \frac{1}{2}RT_0$

(*b*) The above thermodynamic cycle exhibits only isochoric and adiabatic processes.

(*c*) The ratio of heat transfer during processes $1 \to 2$ and $2 \to 3$ is $\left|\frac{Q_{1\to2}}{Q_{2\to3}}\right| = \frac{5}{3}$

(*d*) The ratio of heat transfer during processes $1 \to 2$ and $3 \to 4$ is $\left|\frac{Q_{1\to2}}{Q_{3\to4}}\right| = \frac{1}{2}$

20. One mole of a monoatomic ideal gas undergoes a cyclic process as shown in the figure (where, V is the volume and T is the temperature).



Which of the statements below is (are) true? **(JEE Adv. 2018)**

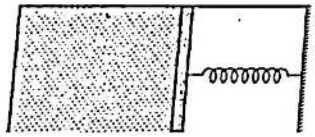
(*a*) Process I is an isochoric process

(*b*) In process II, gas absorbs heat

(*c*) In process IV, gas releases heat

(*d*) Processes I and III are not isobaric

21. An ideal monoatomic gas is confined in a horizontal cylinder by a spring loaded piston (as shown in the figure). Initially the gas is at temperature T_1, pressure p_1 and volume V_1 and the spring is in its relaxed state. The gas is then heated very slowly to temperature T_2, pressure p_2 and volume V_2. During this process the piston moves out by a distance x. **(JEE Adv. 2015)**



Ignoring the friction between the piston and the cylinder, the correct statements is/are

(*a*) If $V_2 = 2V_1$ and $T_2 = 3T_1$, then the energy stored in the spring is $\frac{1}{4}p_1V_1$

(*b*) If $V_2 = 2V_1$ and $T_2 = 3T_1$, then the change in internal energy is $3p_1V_1$

(*c*) If $V_2 = 3V_1$ and $T_2 = 4T_1$, then the work done by the gas is $\frac{7}{3}p_1V_1$

(*d*) If $V_2 = 3V_1$ and $T_2 = 4T_1$, then the heat supplied to the gas is $\frac{17}{6}p_1V_1$

22. An ideal gas is taken from the state A (pressure p, volume V) to a state B (pressure $p/2$, volume $2V$) along a straight line path in a $p-V$ diagram. Select the correct statements from the following. **(IIT-JEE 1...)**

(*a*) The work done by the gas in the process A to B exceeds the work that would be done by it if the system were taken from A to B along an isotherm

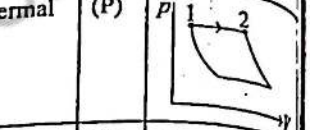
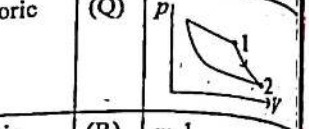
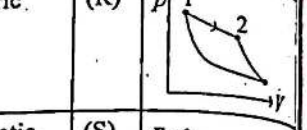
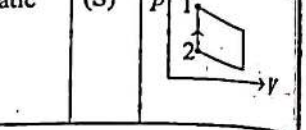
(*b*) In the $T-V$ diagram, the path AB becomes a part of a parabola

(*c*) In the $p-T$ diagram, the path AB becomes a part of a hyperbola

(*d*) In going from A to B, the temperature T of the gas first increases to a maximum value and then decreases

Comprehension Based/Passage Based

Directions (Q.Nos. 131 to 133): Matching the information given in the three columns of the following table.

Column 1		Column 2		Column 3	
(I)	$W_{1\to2} = \frac{1}{\gamma-1}(p_2V_2 - p_1V_1)$	(*i*)	Isothermal	(P)	
(II)	$W_{1\to2} = -pV_2 + pV_1$	(*ii*)	Isochoric	(Q)	
(III)	$W_{1\to2} = 0$	(*iii*)	Isobaric	(R)	
(IV)	$W_{1\to2} = -nRT\ln\left(\frac{V_2}{V_1}\right)$	(*iv*)	Adiabatic	(S)	

An ideal gas is undergoing a cyclic thermodynamic process in different ways as shown in the corresponding p-V diagrams in column 3 of the table. Consider only the path from state 1 to state 2. W denotes the corresponding work done on the system. The equations and plots in the table have standards notations and used in thermodynamic process. Here r is the ratio of heat capacities at constant pressure and constant volume. The number of moles in the gas is n.

23. Which one of the following options correctly represents a thermodynamic process that is used as a correction in the determination of the speed of sound in an ideal gas? **(JEE Adv. 2017)**

(*a*) (IV)(*ii*)(R) (*b*) (I)(*ii*)(Q) (*c*) (I)(*iv*)(Q) (*d*) (III)(*iv*)(R)

24. Which of the following options is the only correct representation of a process in which $\Delta U = \Delta Q - p\Delta V$? **(JEE Adv. 2017)**

(*a*) (II)(*iii*)(S) (*b*) (II)(*iii*)(P) (*c*) (III)(*iii*)(P) (*d*) (II)(*iv*)(R)

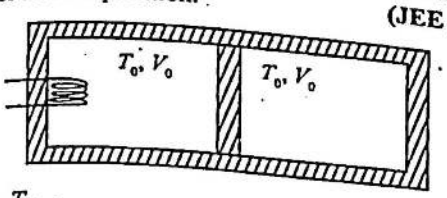
@TAKE_CBSE_X @TABLEDUNET

15. Which one of the following options is the correct combination? **(JEE Adv. 2017)**

(a) (II)(iv)(P) (b) (III)(ii)(S) (c) (II)(iv)(R) (d) (IV)(ii)(S)

Paragraph

A thermally insulating cylinder has a thermally insulating and frictionless movable partition in the middle, as shown in the figure below. On each side of the partition, there is one mole of an ideal gas, with specific heat at constant volume, $C_V = 2R$. Here, R is the gas constant. Initially, each side has a volume V_0 and temperature T_0. The left side has an electric heater, which is turned on at very low power to transfer heat Q to the gas on the left side. As a result the partition moves slowly towards the right reducing the right side volume to $V_0/2$. Consequently, the gas temperatures on the left and the right sides become T_L and T_R, respectively. Ignore the changes in the temperatures of the cylinder, heater and the partition. **(JEE Adv. 2021)**



16. The value of $\frac{T_R}{T_0}$ is ____ **C-24.15 W-25.64 UA-50.21**

(a) $\sqrt{2}$ (b) $\sqrt{3}$ (c) 2 (d) 3

17. The value of $\frac{Q}{RT_0}$ is ____ **C-13.74 W-20.84 UA-65.42**

(a) $4(2\sqrt{2}+1)$ (b) $4(2\sqrt{2}-1)$ (c) $(5\sqrt{2}+1)$ (d) $(5\sqrt{2}-1)$

Match the column

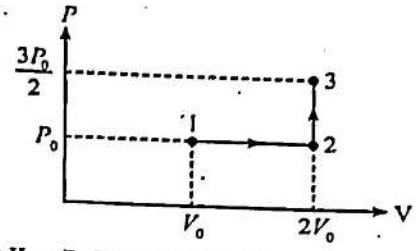
Directions (Q.Nos. 3 to 4): Answer the following by appropriately matching the list based on the information given in the paragraph.

In a thermodynamic process on an ideal monatomic gas, the infinitesimal heat absorbed by the gas is given by $T\Delta X$, where T is temperature of the system and ΔX is the infinitesimal change in a thermodynamic quantity X of the system. For a mole of monatomic ideal gas $X = \frac{3}{2}R\ln\left(\frac{T}{T_A}\right) + R\ln\left(\frac{V}{V_A}\right)$. Here, R is gas constant, V is volume of gas. T_A and V_A are constants.

The List–I below gives some quantities involved in a process and List–II gives some possible values of these quantities.

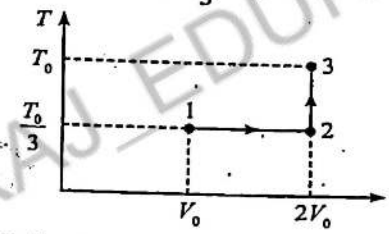
List-I	List-II
I. Work done by the system in process $1 \to 2 \to 3$	(P) $\frac{1}{3}RT_0\ln 2$
II. Change in internal energy in process $1 \to 2 \to 3$	(Q) $\frac{1}{3}RT_0$
III. Heat absorbed by the system in process $1 \to 2 \to 3$	(R) RT_0
IV. Heat absorbed by the system in process $1 \to 2$	(S) $\frac{4}{3}RT_0$
	(T) $\frac{1}{3}RT_0(3+\ln 2)$
	(U) $\frac{5}{6}RT_0$

28. If the process carried out on one mole of monatomic ideal gas is as shown in figure in the P-V-diagram with $P_0V_0 = \frac{1}{3}RT_0$, the correct match is



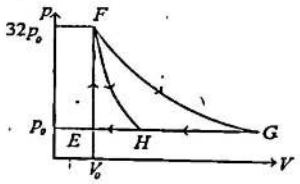
(a) I → Q; II → R; III → S; IV → U
(b) I → Q; II → S; III → R; IV → U
(c) I → Q; II → R; III → P; IV → U
(d) I → S; II → R; III → Q; IV → T

29. If the process on one mole of monatomic ideal gas is as shown in the TV-diagram with $P_0V_0 = \frac{1}{3}RT_0$, the correct match is,



(a) I → P; II → T; III → Q; IV → T
(b) I → S; II → T; III → Q; IV → U
(c) I → P; II → R; III → T; IV → S
(d) I → P; II → R; III → T; IV → P

30. One mole of a monatomic ideal gas is taken along two cyclic processes $E \to F \to G \to E$ and $E \to F \to H \to E$ as shown in the P-V- diagram. **C-57.47, W-22.32, UA-20.22 (JEE Adv. 2013)**



The processes involved are purely isochoric, isobaric, isothermal or adiabatic.

Match the paths in List-I with the magnitudes of the work done in List-II and select the correct answer using the codes given below the lists.

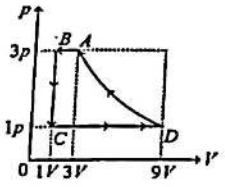
List-I	List-II
P. $G \to E$	1. $160\,p_0V_0\ln 2$
Q. $G \to H$	2. $36\,p_0V_0$
R. $F \to H$	3. $24\,p_0V_0$
S. $F \to G$	4. $31\,p_0V_0$

Codes

P Q R S	P Q R S
(a) 4 3 2 1	(b) 4 3 1 2
(c) 3 1 2 4	(d) 1 3 2 4

@FAKE_CASE_A @RAJ_EDUNET

31. One mole of a monoatomic ideal gas is taken through a cycle *ABCDA* as shown in the p-V diagram. **Column-II** gives the characteristics involved in the cycle. Match them with each of the processes given in **Column-I.** **(IIT-JEE 2011)**

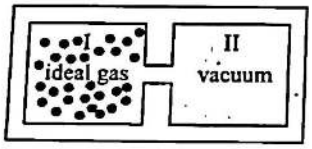


Column-I	Column-II
(A) Process A → B	(p) Internal energy decreases
(B) Process B → C	(q) Internal energy increases
(C) Process C → D	(r) Heat is lost
(D) Process D → A	(s) Heat is gained
	(t) Work is done on the gas

32. Column-I contains a list of processes involving expansion of an ideal gas. Match this with Column-II describing the thermodynamic change during this process. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS. **(IIT-JEE 2008)**

Column-I

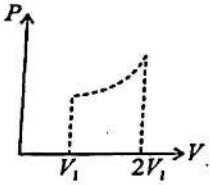
(A) An insulated container has two chambers separated by a valve. Chamber I contains an ideal gas and Chamber II has vacuum. The valve is opened.



(B) An ideal monatomic gas expands to twice its original volume such that its pressure $P \propto \frac{1}{V^2}$, where V is the volume of the gas.

(C) An ideal monatomic gas expands to twice its original volume such that its pressure $P \propto \frac{1}{V^{4/3}}$, where V is its volume gas.

(D) An ideal monatomic gas expands such that its pressure p and volume V follows the behaviour shown in the graph.



Column-II

(p) The temperature of the gas decreases

(q) The temperature of the gas increases or remains constant

(r) The gas loses heat

(s) The gas gains heat

(a) $A \to p, B \to q, r, C \to p,s, D \to p,s$

(b) $A \to r, B \to p, C \to s, D \to q$

(c) $A \to q, B \to p,r, C \to p,s, D \to q,s$

(d) $A \to s, B \to q, C \to p, D \to r$

Multiple Correct

33. A bubble has surface tension S. The ideal gas inside the bubble has ratio of specific heats $\gamma = \frac{5}{3}$. The bubble is exposed to the atmosphere and it always retains its spherical shape. When the atmospheric pressure is P_{a1}, the radius of the bubble is found to be r_1 and the temperature of the enclosed gas is T_1. When the atmospheric pressure is P_{a2}, the radius of the bubble and the temperature of the enclosed gas are r_2 and T_2, respectively. **C-3.94 W-26.6 UA-61.45 (JEE Adv. 2023)**

Which of the following statement(s) is(are) correct?

(a) If the surface of the bubble is a perfect heat insulator, then

$$\left(\frac{r_1}{r_2}\right)^5 = \frac{P_{a_2} + \frac{2S}{r_2}}{P_{a_1} + \frac{2S}{r_1}}$$

(b) If the surface of the bubble is a perfect heat insulator, then the total internal energy of the bubble including its surface energy does not change with the external atmospheric pressure.

(c) If the surface of the bubble is a perfect heat conductor and the change in atmospheric temperature is negligible, then

$$\left(\frac{r_1}{r_2}\right)^3 = \frac{P_{a2} + \frac{4S}{r_2}}{P_{a1} + \frac{4S}{r_1}}.$$

(d) If the surface of the bubble is a perfect heat insulator, then

$$\left(\frac{T_2}{T_1}\right)^{\frac{5}{2}} = \frac{P_{a_2} + \frac{4S}{r_2}}{P_{a_1} + \frac{4S}{r_1}}.$$

34. A mixture of ideal gas containing 5 moles of monatomic gas and 1 mole of rigid diatomic gas is initially at pressure P_0, volume V_0 and temperature T_0. If the gas mixture is adiabatically compressed to a volume $V_0/4$, then the correct statement(s) is/are,

C-10.25 W-15.51 UA-39.87 PC-34.37(JEE Adv. 2019)

(Given $2^{1.2} = 2.3; 2^{3.2} = 9.2$; R is gas constant)

(a) The work $|W|$ done during the process is $13RT_0$

(b) The average kinetic energy of the gas mixture after compression is in between $18RT_0$ and $19RT_0$

(c) The final pressure of the gas mixture after compression is in between $9P_0$ and $10P_0$

(d) Adiabatic constant of the gas mixture is 1.6

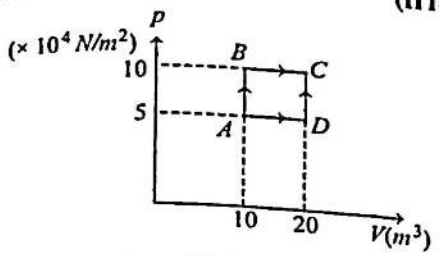
Subjective

35. One mole of a monoatomic ideal gas undergoes an adiabatic expansion in which its volume becomes eight times its initial value. If the initial temperature of the gas is 100 K and the universal gas constant $R = 8.0$ j mol^{-1} K^{-1}, the decrease in its internal energy in joule, is _____. **(JEE Adv. 2018)**

@TAKE_CBSE_X@RAJ_EDUNET

36. A solid body X of heat capacity C is kept in an atmosphere whose temperature is $T_A = 300$ K. At time $t = 0$, the temperature of X is $T_0 = 400$ K. It cools according to Newton's law of cooling. At time t_1 its temperature is found to be 350 K.
At this time (t_1) the body X is connected to a large body Y at atmospheric temperature T_A through a conducting rod of length L, cross-sectional area A and thermal conductivity K. The heat capacity of Y is so large that any variation in its temperature may be neglected. The cross-sectional area A of the connecting rod is small compared to the surface area of X. Find the temperature of X at time $t = 3t_1$. **(IIT-JEE 1998)**

37. A sample of 2 kg monoatomic helium (assumed ideal) is taken through the process ABC and another sample of 2 kg of the same gas is taken through the process ADC (see fig). Given molecular mass of helium = 4. **(IIT-JEE 1997)**



(a) What is the temperature of helium in each of the states A, B, C and D?

(b) Is there any way of telling afterwards which sample of helium went through the process ABC and which went through the process ADC? Write Yes or No.

(c) How much is the heat involved in the process ABC and ADC?

38. One mole of a diatomic ideal gas ($\gamma = 1.4$) is taken through a cyclic process starting from point A. The process $A \rightarrow B$ is an adiabatic compression. $B \rightarrow C$ is isobaric expansion, $C \rightarrow D$ an adiabatic expansion and $D \rightarrow A$ is isochoric.
The volume ratio are $V_A/V_B = 16$ and $V_C/V_B = 2$ and the temperature at A is $T_A = 300$K. Calculate the temperature of the gas at the points B and D and find the efficiency of the cycle. **(IIT-JEE 1997)**

39. A gaseous mixture enclosed in a vessel of volume V consists of one gram mole of gas A with $\gamma = C_p/C_v = 5/3$ and another gas B with $\gamma = 7/5$ at a certain temperature T. The gram molecular weights of the gases A and B are 4 and 32 respectively. The gases A and B do not react with each other and are assumed to be ideal. The gaseous mixture follows the equation $pV^{19/13}$ = Constant, in adiabatic process. **(IIT-JEE 1995)**

(a) Find the number of gram moles of the gas B in the gaseous mixture.

(b) Compute the speed of sound in the gaseous mixture at 300 K.

(c) If T is raised by 1 K from 300 K, find the percentage change in the speed of sound in the gaseous mixture.

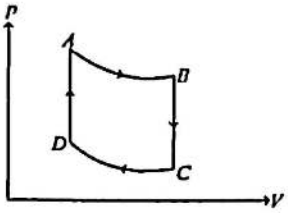
(d) The mixture is compressed adiabatically to 1/5 of its initial volume V. Find the change in its adiabatic compressibility in terms of the given quantities.

40. An ideal gas is taken through a cyclic thermodynamic process through four steps. The amounts of heat involved in these steps are $Q_1 = 5960$J, $Q_2 = -5585$J, $Q_3 = -2980$J and $Q_4 = 3645$ J respectively. The corresponding quantities of work involved are $W_1 = 2200$ J, $W_2 = -825$ J, $W_3 = -1100$ J and W_4 respectively. **(IIT-JEE 1994)**

(a) Find the value of W_4.

(b) What is the efficiency of the cycle?

41. One mole of a monoatomic ideal gas is taken through the cycle shown in figure **(IIT-JEE 1993)**



$A \rightarrow B$: adiabatic expansion

$B \rightarrow C$: cooling at constant volume

$C \rightarrow D$: adiabatic compression

$D \rightarrow A$: heating at constant volume.

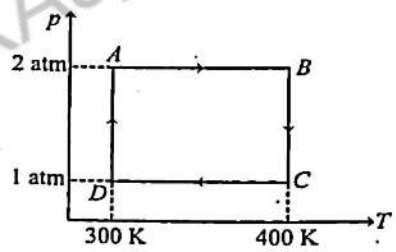
The pressure and temperature at A, B, etc., are denoted by p_A, T_A, p_B, T_B etc., respectively. Given that, $T_A = 1000$ K, $p_B = (2/3)p_A$ and $p_C = (1/3)\,p_A$, calculate the following quantities

(a) The work done by the gas in the process $A \rightarrow B$.

(b) The heat lost by the gas in the process $B \rightarrow C$.

(c) The temperature T_D. (Given : $(2/3)^{2/5} = 0.85$)

42. Two moles of helium gas undergo a cyclic process as shown in figure. Assuming the gas to be ideal, calculate the following quantities in this process. **(IIT-JEE 1992)**



(a) The net change in the heat energy.

(b) The net work done.

(c) The net change in internal energy.

43. Three moles of an ideal gas $\left(C_p = \frac{7}{2}R\right)$ at pressure, p_A and temperature T_A is isothermally expanded to twice its initial volume. It is then compressed at constant pressure to its original volume. Finally gas is compressed at constant volume to its original pressure p_A. **(IIT-JEE 1991)**

(a) Sketch p-V and p-T diagrams for the complete process.

(b) Calculate the net work done by the gas, and net heat supplied to the gas during the complete process.

44. An ideal gas having initial pressure p, volume V and temperature T is allowed to expand adiabatically until its volume becomes 5.66 V while its temperature falls to $T/2$. **(IIT-JEE 1990)**

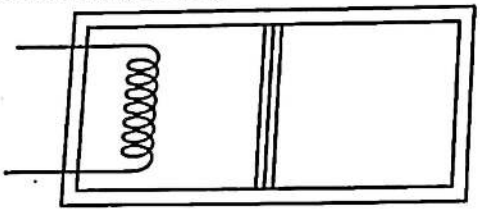
(a) How many degrees of freedom do gas molecules have?

(b) Obtain the work done by the gas during the expansion as a function of the initial pressure p and volume V.

@IITJEE_KEY_@RAJEDUNET

45. Two moles of helium gas $\left(\gamma = \frac{5}{3}\right)$ are initially at temperature 27°C and occupy a volume of 20 L. The gas is first expanded at constant pressure until the volume is doubled. Then it undergoes an adiabatic change until the temperature returns to its initial value.
What are the final volume and pressure of the gas? Sketch the process on P – V diagram and find the work done by the gas
(IIT-JEE 1988)

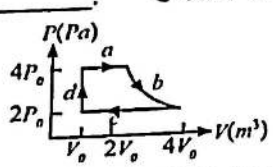
46. The rectangular box shown in figure has a partition which can slide without friction along the length of the box. **(IIT-JEE 1984)**

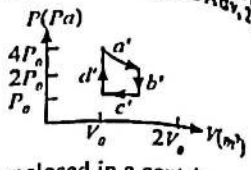


Initially each of the two chambers of the box has one mole of a monatomic ideal gas ($\gamma = 5/3$) at a pressure P_0, volume V_0 and temperature T_0. The chamber on the left is slowly heated by an electric heater. The walls of the box and the partition are thermally insulated. Heat loss through the lead wires of the heater is negligible. The gas in the left chamber expands pushing the partition until the final pressure in both chambers becomes $\frac{243p_0}{32}$. Determine (*a*) the final temperature of the gas in each chamber and (*b*) the work done by the gas in the right chamber.

Fill In the Blanks

47. One mole of an ideal gas undergoes two different cyclic processes I and II, as shown in the P–V diagrams below. In cycle I, processes *a*, *b*, *c* and *d* are isobaric, isothermal, isobaric and isochoric, respectively. In cycle II, processes a', b', c' and d' are isothermal, isochoric, isobaric and isochoric, respectively. The total work done during cycle I is W_I and that during cycle II is W_{II}. The ratio W_I/W_{II} is _____.
C-44.24 W-42.59 UA-13.17 (JEE Adv, 2021)





48. Consider one mole of helium gas enclosed in a container at initial pressure P_1 and volume V_1. It expands isothermally to volume $4V_1$. After this, the gas expands adiabatically and its volume becomes $32V_1$. The work done by the gas during isothermal and adiabatic expansion processes are W_{iso} and W_{adia}, respectively. If the ratio $\frac{W_{iso}}{W_{adia}} = f \ln 2$, then f is _____.
C-13.66 W-72.49 UA-13.85 (JEE Adv, 2021)

49. An ideal gas with pressure p, volume V and temperature T is expanded isothermally to a volume $2V$ and a final pressure p_1. If the same gas is expanded adiabatically to a volume $2V$, the final pressure is p_a. The ratio of the specific heats of the gas is 1.67. The ratio p_a/p_1 is ..... **(IIT-JEE 1994)**

True/False

50. At a given temperature, the specific heat of a gas at a constant pressure is always greater than its specific heat at constant volume. **(IIT-JEE 1987)**

@TAKE_CBSE_X @RAJ_EDUPET

ANSWER KEY

JEE-Main

1. (*d*)	2. (*a*)	3. [*d*]	4. (*a*)	5. (*b*)	6. (*a*)	7. [60.80,60.81]		8. (*d*)	9. (*d*)
10. (*d*)	11. (*d*)	12. (*d*)	13. (*c*)	14. (*b*)	15. (*c*)	16. (*b*)	17. [750]	18. [2]	19. (*b*)
20. [60]	21. [100]	22. [25]	23. (*a*)	24. (*b*)	25. (*b*)	26. (Bonus)	27. (Bonus)	28. (*a,c*)	29. (*c*)
30. (*d*)	31. (*a,b*)	32. (*d*)	33. (*c*)	34. (*b*)	35. (*c*)	36. (*a*)	37. (*c*)	38. (*a*)	39. (*b*)
40. (*d*)	41. [2]	42. (*a*)	43. (*b*)	44. (*d*)	45. (*d*)	46. (*b*)	47. (*b*)	48. (*b*)	49. (*d*)
50. (*a*)	51. (*c*)	52. (*c,d*)	53. (*b*)	54. (*b,c,d*)	55. (*c*)	56. [25]	57. (*d*)	58. (*a*)	59. (*c*)
60. (*b*)	61. [17258]	62. [50]	63. [1.77 to 1.78]		64. [2.05]	65. (*a*)	66. (*d*)	67. (*a*)	68. (*a*)
69. (*b*)	70. (*a*)	71. (*a*)	72. (*a*)	73. [1819]	74. [46]	75. (*d*)	76. (*c*)	77. (*c*)	78. (*b*)
79. (*d*)	80. (*d*)	81. (*a*)	82. (*b*)	83. [31]	84. [540]	85. [102]	86. (*d*)	87. (*c*)	88. (*d*)
89. (*b*)	90. [500]	91. [208]	92. (*d*)	93. (*d*)	94. [8791]	95. [19]			

JEE-Advanced

1. (*b, c*)	2. [2]	3. [–972]	6. (*b*)	7. (*b*)	8. (*a*)	9. (*b*)	10. (*d*)	11. (*c*)	12. (*c*)
13. (*b*)	14. (*a*)	15. (*a*)	16. (*c*)	17. (*c*)	18. (*b,c,d*)	19. (*a, c*)	20. (*b, c, d*)	21. (*a, b, c*)	
22. (*a, b, d*)	23. (*c*)	24. (*b*)	25. (*b*)	26. (*a*)	27. (*b*)	28. (*a*)	29. (*d*)	30. (*a*)	
31. (A) → (p, r, t); (B) →(p, r); (C) →(q, s);(D) →(r, t)				32. (*c*)	33. (*c, d*)	34. (*a,c,d*)	35. [900]	36. [2]	37. [1.78]
38. [True]									

EXPLANATIONS

JEE-Main

1. (d) For, Isobaric process
$W = nR\Delta T = 200$ J
$\gamma = 1 + \frac{2}{f} = 1.4 \Rightarrow \frac{2}{f} = 0.4 \Rightarrow f = 5$
$Q = \left(\frac{f+2}{2}\right) nR\Delta T$
$= \frac{7}{2} \times 200 = 700$ J

2. (a) Change in internal energy for cyclic process in zero.
$\Delta U = 0$
$\Delta Q = W$ = area of P-V curve.
$= \pi \times (140 \times 10^3 \text{ Pa}) \times (140 \times 10^{-6} \text{ m}^3)$
$\Delta Q = 61.6$ J

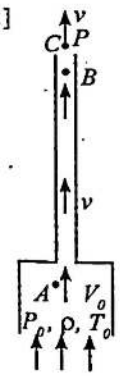
3. (d) From first law of thermodynamics
$\Delta Q - \Delta U = W$
$48 - nC_v\Delta T = W$
$\Rightarrow 48 - (1)\left(\frac{3R}{2}\right) = W$
$\Rightarrow W = 48 - 3 \times R$
$\Rightarrow W = 48 - 3 \times (8.3) = 23.1$ J

4. (a) Work done during the phase change
$= P\Delta V = 3 \times 10^5 \times 1600 \times 10^{-6} = 480$ J
Only 10% of heat is used for work done.
Hence $Q = 4800$ J
The rest goes in internal energy, which is 90% of the heat.
Change in internal energy
$= 0.9 \times 4800 = 4320$ J

5. (b) Work done = Area of triangle
$\Rightarrow W = +\frac{1}{2}(4-2) \times (400-100)$
$W = 300$J

6. (a) From first law of thermo
$\Delta U = \Delta Q - \Delta W = mL_v - P\Delta$
$= (1)(2257 \times 10^3) - (1 \times 10^5)(1.671 - 1 \times 10^3)$
$= 2257 \times 10^3 - 167 \times 10^3 = 2090 \times 10^3$ J
$= 2090$ kJ

7. [60.80,60.81]



JEE-Main

$P_0T_0 = \rho T \Rightarrow 1.2 \times 300 = \rho(360) \Rightarrow \rho = 1$
Between A & B
$P_0 + \frac{1}{2}\rho V_0^2 = P + \frac{1}{2}\rho V^2 + \rho gh$ ...(i)
$\frac{\pi D^2}{4} V_0 = \frac{\pi d^2}{4} V$ ...(ii)
Between B & C
$P + \frac{1}{2}\rho V^2$
$= P_0 - \rho_0 g(H+h) + \frac{1}{2}\rho V^2$ ...(iii)
using equation (i) and (ii)
$P_0 + \frac{1}{2}\rho\left(V\frac{d^2}{D^2}\right)^2 = P + \frac{1}{2}\rho V^2 + \rho gh$
$\Rightarrow \rho_0 g(H+h)\ \frac{1}{2}\rho V^2\left[1 - \frac{d^4}{D^4}\right] + \rho gh$
$\Rightarrow V_2 = \frac{2\rho_0}{\rho} g(H+h) - 2gh$
$= 2 \times 1.2 \times 10 \times 10 - 2 \times 10 \times 9 = 60$
$Q_m = \rho\frac{\pi d^2}{4} V = 1 \times \frac{\pi}{4} \times 10^{-2} \times \sqrt{6}$
$= 60.80$ 60.80 to 60.81

8. (d) From first law of thermodynamics
Internal energy (U) = Total energy (Q) – Work done (W)
$\frac{dU}{dt} = \frac{dQ}{dt} - \frac{dw}{dt}$
$\frac{dU}{dt} = 1000 - 200 = 800W$

9. (d) If heat is added to a system (Isothermal) then temperature will remain constant.
...ce statement-I is false
...ement-I: is false
Statement-II: If work done is positive then $\int PdV > 0$
Hence volume of system must increase during positive work done by the system.
So statement II is true

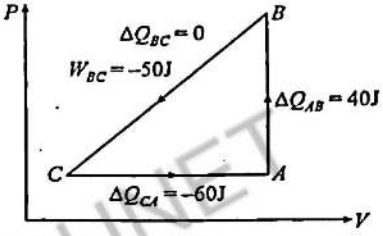
10. (d) As there is no exchange of heat, therefore $\Delta q = 0$
$\Delta u = -W$
$\because W = \int PdV$
$\Rightarrow \Delta u = 30 \times 10^3 \times 150 \times 10^{-6} = 4500 \times 10^{-3}$
$\Rightarrow \Delta u = 4.5$ J

11. (d) Work done = Area under curve
$= \frac{6P_1 \times 3V_1}{2} = 9P_1V_1$

12. (d) $dQ = dU + dW \Rightarrow dU = nC_v dT$
$dU = 0$ (for isothermal)
$\therefore U$ = constant
Also $dQ > 0$ (supplied)
Hence $dW > 0$

13. (c) If dW is work done on the system there, according to First law of thermodynamics $dQ = dU - dW$.

14. (b)



$\Delta Q_{cycle} = 40 - 60 = \Delta W$
$\Delta W = -20J = W_{BC} + W_{CA}$
$W_{CA} = -20J - W_{BC} = -20 - (-50) = 30J$

15. (c) We know that 22.4 litres of He = 1 mole
44.4 litres of He $= \frac{44.8}{22.4}$ moles = 2 mole
$\therefore n = 2$ moles of He
By using, $Q = nC_v\Delta T$ (for fixed capacity (v = constant)
$= 2 \times \frac{R}{\gamma - 1}\Delta T = \frac{2 \times R}{\frac{5}{3} - 1} \times 20 = 2 \times \frac{3R}{2} \times 20$
$Q = 60R = 60 \times 8.3 = 498$ J

16. (b) $\frac{C_P}{C_v} = 1 + \frac{2}{f} = 1.4 \Rightarrow f = 5$
By conservation of energy
$\frac{f}{2} nR\Delta T = \frac{1}{2} Mv^2$
$\Delta T = \frac{Mv^2}{fR} = \frac{Mv^2}{5R}$

17. [750] $W = nR\Delta T = 150$J
$H = \Delta U + W$
$= \frac{f}{2} nR\Delta T + nR\Delta T$
$= (4+1)\, nR\Delta T = 5 \times 150 = 750J$

18. [2] From first Law of Thermodynamics,
$Q = \Delta U + W$
$\Rightarrow Q = \Delta U + \frac{Q}{4}$
$\Rightarrow \Delta U = \frac{3Q}{4}$
$\Rightarrow nC_v\Delta T = \frac{3}{4} nC\Delta T$

FAKE_CBSE_@RAJ_RUNET

$\Rightarrow C = \frac{4}{3}C_v = \frac{4}{3}\times\frac{3}{2}R$

$\left[\text{For monoatomic gases, } C_v = \frac{3}{2}R\right]$

$\therefore C = 2R$

19. (*b*) (A) $\Delta U = \Delta Q - \Delta W$

$= \left\{\left(10^{-3}\times 2250\right) - \frac{10^5\left(10^{-3}-10^{-6}\right)}{10^3}\right\}$ kJ.

$= (2.25 - 0.00099)$ kJ $= (2.1501)$ kJ

(B) $U = nC_V\Delta T = \frac{5}{2}nR\Delta T$

$= \frac{5}{2}\cdot(0.2)(8)(1500-500)J = 4$ kJ

(C) $P_1V_1^{\gamma} = P_2V_2^{\gamma}$

$\Rightarrow 2\left(\frac{1}{3}\right)^{5/3} = P_2\left(\frac{1}{24}\right)^{5/3} \Rightarrow P_2 = 64$kPa

$\Delta U = nC_v\Delta T = \frac{3}{2}\cdot\left(P_2V_2 - P_1V_1\right)$

$= \frac{3}{2}\left(64\times\frac{1}{24} - 2\times\frac{1}{3}\right)kJ = 3$ kJ

(D) $\Delta U = nC_v\Delta T$

$= n\cdot\frac{7}{2}R\Delta T = \frac{7}{9}\Delta Q = 7$ kJ

20. [60] Work done $W = \int PdV$

$W = \int\frac{nRT}{V}dV = \int\frac{nRT}{KT^{2/3}}dV$

$W = \int_{T_1}^{T_2}\frac{nRT}{KT^{2/3}}\left(\frac{2}{3}KT^{-1/3}\right)dT$

After solving above equation

$W = \frac{2}{3}nR\left(T_2 - T_1\right)$

$W = \frac{2}{3}nR\times 90 = 60nR$

Let assume, number of mole-1

$\therefore W = 60R \Rightarrow x = 60$

21. [100] Heat absorbed in cyclic process = Work done = area of circle of radius 10 = 100π Joule

22. [25] First law of thermodynamics.

$\Delta Q = \Delta U + \Delta W$

$Q = \Delta U + \frac{Q}{5} \Rightarrow \Delta U = \frac{4Q}{5}$

$\Delta U = nC_v\Delta T$

$\Rightarrow \frac{4Q}{5} = \frac{5R}{2}\Delta T \Rightarrow \Delta T = \frac{8Q}{25R}$

$\therefore Q = nC\Delta T = 1\times C\times\frac{80}{25R}$

$\Rightarrow C = \frac{25R}{8} \Rightarrow x = 25$

23. (*a*) $\therefore$ Here, θ is heat flows in the system whem path ACB is used and a is heat flows when path ADB is used.

$Q - W = Q' - W'$

$60 - 30 = Q' - 10$

$Q' = 40$ J

24. (*b*) Work done $= nR\Delta T = nR(T_2 - T_1)$

$= \frac{1}{2}\times 8.31\times(90-20) = 290.85$ J

25. (*b*) Given: $P \propto T^3 \Rightarrow PT^{-3} =$ constant

$\Rightarrow PV^{\gamma} =$ constant

$\Rightarrow P\left(\frac{nRT}{P}\right)^{\gamma} =$ constant [As $PV = nRT$]

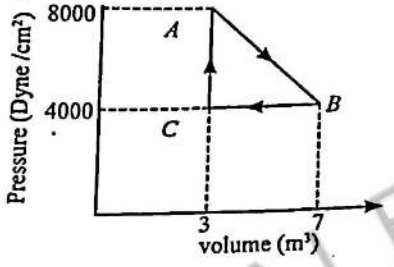
$\Rightarrow P^{1-\gamma}T^{\gamma} =$ constant

$\Rightarrow PT^{\frac{\gamma}{1-\gamma}} =$ constant $\Rightarrow \frac{\gamma}{1-\gamma} = -3$

$\Rightarrow \gamma = -3 + 3\gamma$

$\Rightarrow 3 = 2\gamma \Rightarrow \gamma = \frac{3}{2}$

26. (Bonus)



Work done $AB = \frac{1}{2}$ (8000 + 6000)Dyne/cm² × 4m³ = (60000 Dyne/cm²) × 4m³

Work done $BC = -$(4000 Dyne/cm²) × 4m³

The total work done by the gas from A to B and B to C

Total work done = 2000 Dyne/cm² × 4m³

$= 2\times 10^3\times\frac{1}{10^5}\frac{N}{cm^2}\times 4\text{ m}^3$

$= 2\times 10^{-2}\times\frac{N}{10^{-4}m^2}\times 4m^3$

$= 2\times 10^2\times 4$ Nm $= 800$ J

27. (Bonus) From graph,

For process A,

Slope given is $\tan^{-1}\gamma$

Hence,

$\log P = \gamma\log V$

$\Rightarrow P = V^{\gamma}, (\gamma > 1)$

$\Rightarrow PV^{-\gamma} =$ Constant

$C_A = C_V + \frac{R}{1+\gamma}$ ...(*i*)

In same way, for process B

Slope given is 45 degrees.

Hence,

$PV^{-1} =$ constant

$C_B = C_v + \frac{R}{1+1}$

$C_B = C_v + \frac{R}{2}$ ...(*ii*)

As we know that,

$C_p = C_v + R$

By (*I*), (*II*) & (*III*)

$C_p > C_B > C_A > C_v$

[No answer matching]

28. (*a* & *c*) Steeper curve (B) is adiabatic

Adiabatic $\Rightarrow PV^{\gamma} =$ const.

Or $P\left(\frac{T}{P}\right)^{\gamma} =$ const.

$\frac{T^{\gamma}}{P^{\gamma-1}} =$ const.

Curve (A) is isothermal

$T =$ const.

$PV =$ const.

29. (*c*) $f_1 = 3, f_2 = 5$

$n_1 = 3, n_2 = 2$

$f_{mixture} = \frac{n_1f_1 + n_2f_2}{n_1 + n_2} = \frac{9+10}{f} = \frac{19}{5}$

the value of adiabatic exponent γ for mixture

$\gamma_{mixture} = 1 + \frac{2\times 5}{19} = \frac{29}{19} = 1.52$

30. (*d*) For ideal gas, $PV = nRT$

$V = \left(\frac{nR}{P}\right)T$

Slope of the graph $= \frac{nR}{P}$

Slope $\propto \frac{1}{P}$

$(\text{Slope})_2 > (\text{Slope})_1$

Therefore, $P_2 > P_1$

31. (*a*, *b*) For adiabatic process, work done

$W = \frac{nR\Delta T}{1-x}$ $\left[\text{Here, } x = \frac{3}{2}\right]$

$W = \frac{P_2V_2 - P_1V_1}{-\frac{1}{2}} = 2(P_1V_1 - P_2V_2)$

If work done by external is asked then

$W = -2(P_1V_1 - P_2V_2)$

32. (*d*) Work done in adiabtic process

$W = \frac{nR\Delta T}{1-\gamma}$

$TV^{\gamma-1} =$ constant

$TV^{\gamma-1} = T_f(2V)^{\gamma-1}$

$T_f = T\left(\frac{1}{2}\right)^{1/2} = \frac{T}{\sqrt{2}}$

$W = \frac{R\left(\frac{T}{\sqrt{2}} - T\right)}{1-\frac{3}{2}} = 2RT\frac{\left(\sqrt{2}-1\right)}{\sqrt{2}}$

$= RT\left(2-\sqrt{2}\right)$

@AKE_CBSE_GRAL_EDUNET

33. (c) $P \propto T^3$

PT^{-3} constant

$PV = nRT$ (ideal gas equation)

$(P)(PV)^{-3}$ = constant

$P^{-2}V^{-3}$ = constant ...(1)

Process equation for adiabatic process is

PV^{γ} = constant ...(2)

Comparing equation (1) and (2)

$\frac{C_p}{C_v} = \gamma = \frac{3}{2}$

34. (b) Given $PV^2 = RT$

$P(2VdV) = RdT$ ($\because P$ = constant)

$PdV = \frac{RdT}{2V}$ ...(i)

From first law of thermodynamic

$dQ = dU + dW$

$CdT = C_V dT + PdV$ ...(ii)

From equations (i) & (ii)

$C = C_V + \frac{R}{2V}$

35. (c) we have given two different adiabatic paths for the same gas intersect two isothermal curves as shown in P-V diagram

For adiabatic process, $TV^{\gamma-1}$ constant

$\Rightarrow T_a \cdot V_a^{\gamma-1} = T_d \cdot V_d^{\gamma-1}$

$\left(\frac{V_a}{V_d}\right)^{\gamma-1} = \frac{T_d}{T_a}$

$\Rightarrow T_b \cdot V_b^{\gamma-1} = T_c \cdot V_c^{\gamma-1}$

$\left(\frac{V_b}{V_c}\right)^{\gamma-1} = \frac{T_c}{T_b}$

$\frac{V_a}{V_d} = \frac{V_b}{V_c}$ $\left(\because T_d = T_c,\ T_a = T_b\right)$

36. (a) Work done in the isobaric process,

$w = P\Delta v = nR\Delta T = 100$ J

$Q = \Delta u + w$

$\Delta Q = nC_V\Delta T + nR\Delta T$

$\left(\frac{5}{2}+1\right)100 = 350J$ $\left[\text{As } C_V = \frac{5}{2}R\right]$

37. (c) As, process is adiabatic

$\Rightarrow P_iV_i = P_fV_f^{\gamma}$

$\Rightarrow P_i(5)^{1.5} = P_f(4)^{1.5}$

$\Rightarrow \frac{P_i}{P_f} = \left(\frac{4}{5}\right)^{\frac{3}{2}} = \frac{4}{5}\cdot\left(\frac{4}{5}\right)^{\frac{1}{2}} \Rightarrow \frac{8}{5\sqrt{5}}$

38. (a) For, adiabatic Process, $TV^{\gamma-1}$ = constant

$\Rightarrow T(V)^{\frac{3}{2}-1} = T_f(2V)^{\frac{3}{2}-1}$

$\Rightarrow T_f = \left(\frac{T}{\sqrt{2}}\right)$

Now, Work done

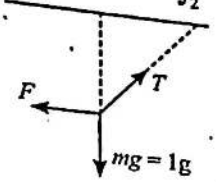
$= \frac{nR\Delta T}{1-\gamma} = \frac{1\cdot R\left[\frac{T}{\sqrt{2}} - T\right]}{1-\frac{3}{2}}$

$\Rightarrow$W.D. $= RT\left[2-\sqrt{2}\right]$

39. (b) Work done through the process AB

$W_{AB} = \int PdV$ (Assuming T to be constant which should be given in question)

$= \int \frac{RTdV}{V^3} = RT\int_2^4 V^{-3}dV$



$= 8\times300\times\left(-\frac{1}{2}\left[\frac{1}{4^2} - \frac{1}{2^2}\right]\right) = 225$ J

Work done through the process BC,

$W_{BC} = P\int_4^2 dV = 10(2-4) = -20$ J

$W_{CA} = 0$

$\therefore W_{cycle} = 205$ J

40. (d) $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$TV^{1/2} = T_2(2V)^{1/2}$

$\therefore T_2 = \frac{T}{\sqrt{2}}$

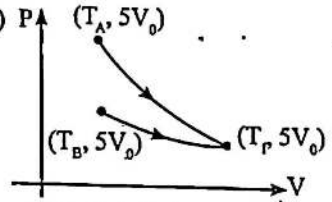
$\Rightarrow W = \frac{R(T_1-T_2)}{\gamma-1} = \frac{R\left(T-\frac{T}{\sqrt{2}}\right)}{\frac{1}{2}}$

$= RT\left(2-\sqrt{2}\right)$

41. [2] $\frac{W_I}{W_{II}} = \frac{4P_0V_0 + 8P_0V_0\ell n2 - 6P_0V_0 - 0}{4P_0V_0\ell n2 - 0 - P_0V_0 + 0}$

$= \frac{8\ell n2 - 2}{4\ell n2 - 1} = 2$

42. (a)



For adiabatic, $TV^{\gamma-1}$ = constant.

$\therefore T_AV_0^{\gamma-1} = T_f(5V_0)^{\gamma-1}$

$\frac{T_A}{T_f} = 5^{\gamma-1} = \frac{T_A}{T_B}$

43. (b) Since gas is suddenly compressed, therefore the processes would be adiabatic. i.e.,

PV^{γ} = constant.

$\Rightarrow P_1V_1^{\gamma} = P_2V_2^{\gamma}$

$\Rightarrow P_0V_0^{\gamma} = P_2\left(\frac{V_0}{4}\right)^{\gamma}$

$\Rightarrow P_2 = P_0(4)^{\gamma}$

44. (d) For gas A : Isothermal process, $\Rightarrow$ PV = constant

$P_1V_1 = P_2V_2$

$PV = P_A(V/8) \Rightarrow P_A = 8P$

For gas B :

Adiabatic process $\Rightarrow PV^{\gamma}$ constant

For monoatomic gas $\gamma = \frac{5}{3}$.

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$

$\frac{P_B}{P} = \left(\frac{V_1}{V_2}\right)^{\gamma} = \left(\frac{V}{V/8}\right)^{\frac{5}{3}} \Rightarrow P_B = 32P$

$\therefore \frac{P_B}{P_A} = \frac{32P}{8P} = 4$

45. (d) (1) $\Delta Q = 0$

(2) $\Delta Q = \Delta U + \Delta W$

The compression (Volume decreases) is adiabatic so no heat is absorbed and the work done is used to increase the temperature

Hence internal energy will change and it will equal to the work done on the gas.

$\Rightarrow \Delta U = -\Delta W$

$\Delta W = -ve \Rightarrow \Delta U = +ve$

$\Delta U\uparrow \Rightarrow T\uparrow$

$\Delta U \neq 0$

46. (b) $\because \Delta U = nC_v\Delta T$

For an isothermal process T remains constant

$\Rightarrow \Delta U = 0 \Rightarrow A \longrightarrow II$

$\because \Delta Q = \Delta U + \Delta W$

For an Adiabatic process

$\Delta Q = 0$

$\Rightarrow \Delta U = -\Delta W$

Work done by a gas is positive

So ΔU is negative $\Rightarrow B \longrightarrow I$

For an Isochoric process $\Delta W = 0$

$C \longrightarrow IV$

For Isobaric process

$\Delta W = P\Delta V \neq 0$, $\Delta U = nCv\Delta T \neq 0$

Heat absorbed goes partly to increase internal energy and partly to do work.

47. (b) For constant temp. the thermodynamic process is isothermal and

For = constant temp. $\Rightarrow$ internal energy is constant

@FAKE_CBSE_X @RAJ_EDUNET

48. (*b*) Given, $P = aV^{-3} \Rightarrow PV^3 = a$
Differentiating w.r.t to pressure

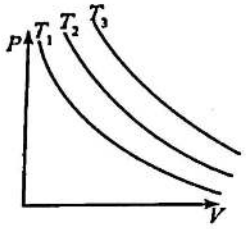
$$V^3 + 3PV^2\frac{dV}{dP} = 0$$

$$V = -3\frac{PdV}{dP} \Rightarrow \frac{dP.V}{dV} = -3P$$

$$B = -\frac{dP}{dV/V}$$

$$\therefore B = -\left(\frac{dPV}{dV}\right) = -(-3P) = 3P$$

49. (*d*) For isothermal process P-V graph is rectangular hyperbola



As dotted line is isobaric line which implies $T_3 > T_2 > T_1$ as volume is increasing.

50. (*a*) Using equation, $PV^\gamma =$ Constant,

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^\gamma$$

$$\frac{81}{16} = \left(\frac{27}{8}\right)^\gamma$$

$$\left(\frac{3}{2}\right)^4 = \left(\frac{3}{2}\right)^{3\gamma} \Rightarrow \gamma = \frac{C_P}{C_V} = \frac{4}{3}$$

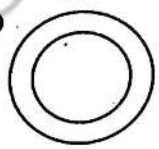
51. (*c*) Constant entropy means process is adiabatic
$PV^\gamma =$ constant

$$P_1V_1^\gamma = P_2V_2^\gamma$$

$$P_1V_1^\gamma = P_2\left(\frac{V_1}{8}\right)^{5/3} \qquad \left[V_2 = \frac{V_1}{8}\right]$$

$$PV_1^{5/3} = \frac{P_2V_1^{5/3}}{32} \Rightarrow P_2 = 32P$$

52. (*c, d*)



$$P_{gas} = P_a + \frac{4S}{r}$$

$PV^\gamma =$ constant [adiabatic process]

$$\left(Pa_1 + \frac{4S}{r_1}\right)\left(\frac{4}{3}\pi r_1^3\right)^{5/3}$$

$$= \left(P_{a_2} + \frac{4S}{r_2}\right)\left(\frac{4}{3}\pi r_2^3\right)^{5/3}$$

$$\frac{r_1^3}{r_2^3} = \left(\frac{P_{a_2} + \frac{4S}{r_2}}{P_{a_1} + \frac{4S}{r_1}}\right)$$

$p^{1-\gamma}T^\gamma =$ constant

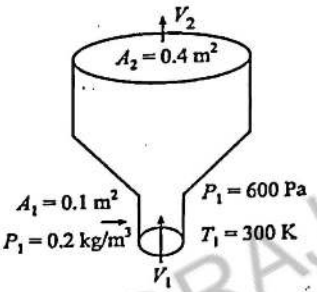
$$\left(P_{a_2} + \frac{4S}{r_2}\right)^{1-5/3} T_2^{5/3} = \left(P_{a_1} + \frac{4S}{r_1}\right)^{1-5/3} T_1^{5/3}$$

$$\left(\frac{T_2}{T_1}\right)^{5/3} = \left(\frac{P_{a_1} + \frac{4S}{r_1}}{P_{a_2} + \frac{4S}{r_2}}\right)^{-2/3}$$

$$\left(\frac{T_2}{T_1}\right)^{5/2} = \left(\frac{P_{a_2} + \frac{4S}{r_2}}{P_{a_1} + \frac{4S}{r_1}}\right)$$

d is correct.

53. (*b*)



$$\frac{dm}{dt} = \rho_1 A_1 V_1 = 0.8\,kg/s \text{ or}$$

$$V_1 = \frac{0.8}{0.2 \times 0.1} = 40\,m/s$$

$g = 10\ m/s^2$
$\gamma = 2$, $P^{1-\gamma}T^\gamma = constant$
Gas undergoes adiabatic expansion,

$$\frac{P_2}{P_1} = \left(\frac{T_1}{T_2}\right)^{\frac{\gamma}{1-\gamma}}$$

$$P_2 = \left(\frac{300}{150}\right)^{\frac{2}{-1}} \times 600$$

$$P_2 = \frac{600}{4} = 150\,Pa$$

ow $\rho = \frac{PM}{RT} \Rightarrow \rho \propto \frac{P}{T}$

$$\frac{\rho_1}{\rho_2} = \left(\frac{P_1}{P_2}\right)\left(\frac{T_2}{T_1}\right) = \left(\frac{150}{600}\right)\left(\frac{300}{150}\right) = \frac{1}{2}$$

$$\rho_2 = \frac{\rho_1}{2} = 0.1\,kg/m^3$$

Now

$$\rho_2 A_2 V_2 = 0.8 \Rightarrow V_2 = \frac{0.8}{0.1 \times 0.4} = 20\,m/s$$

Now work done *W* on gas = $\Delta K + \Delta U +$ Internal energy

$$P_1A_1\Delta x_1 - P_2A_2\Delta x_2$$

$$= \frac{1}{2}\Delta mV_2^2 - \frac{1}{2}\Delta mV_1^2 + \Delta mgh + \frac{f}{2}$$

$$(P_2\Delta V_2 - P_1\Delta V_1)$$

$$\Rightarrow 2P_1\frac{\Delta V_1}{\Delta m} - 2P_2\frac{\Delta V_2}{\Delta m} = \frac{V_2^2 - V_1^2}{2} + 0$$

$$\Rightarrow \frac{2\times600}{0.2} - \frac{2\times150}{0.1} = \frac{20^2 - 40^2}{2} + 10h$$

$h = 360$ m

54. (*b, c, d*) For adiabatic process ($A \to B$)

$$P_AV_A^\gamma = P_BV_B^\gamma$$

$$10^5 \times (0.8)^{\frac{5}{3}} = 3\times10^5\left(V_B\right)^{\frac{5}{3}}$$

$$\Rightarrow V_B = 0.8 \times \left(\frac{1}{3}\right)^{0.6} = 0.4$$

Work done in process $A \to B$

$$W_{AB} = \frac{P_AV_A - P_BV_B}{\gamma - 1}$$

$$\Rightarrow W_{AB} = 0\ 60\ kJ$$

$$\Rightarrow |W_{AB}| = 60\ kJ$$

Work done $B \to C$ in process (Isotherm process)

$$W_{BC} = nRT\ell n\frac{V_C}{V_B} = P_BV_B\ell n\frac{V_C}{V_B}$$

$$\Rightarrow W_{BC} = 3\times10^5 \times 0.4\ell n\frac{0.8}{0.4}$$

$$\Rightarrow W_{BC} = 84\ kJ$$

Work done in process $C \to A$

$$W_{CA} = P\Delta V = 0 \qquad (\because V_2$$

So total work done in the process

$A \to B \to C$

$$W_{ABC} = W_{AB} + W_{BC} + W_{CA}$$

$$= 60 + 84 + 0,\ W_{ABC} = 24\ kJ.$$

55. (*c*) Pressure decreases with increase volume, in both isothermal and adiabatic process. In adiabatic process, volume decreases and pressure increases with increase in temperature

56. [25] As pressure is not changing, so it isobaric process.

$$\Rightarrow \Delta U = nC_v\Delta T$$

$$\Delta U = n\left(\frac{5}{2}R\right)\Delta T \qquad \left[C_v = \frac{5}{2}\right.$$

$$\Delta W = nR\Delta T$$

$$\therefore \frac{\Delta U}{\Delta W} = \frac{\frac{5}{2}nR\Delta T}{nR\Delta T} = \frac{5}{2}$$

$$\frac{5}{2} = \frac{x}{10} \Rightarrow x = 25.00$$

@FAKE_CBSE_Y @RAJ_EDUNET

57. (d) The given process is isochoric, so the amount of heat required,

$$Q = nC_V\Delta T = n\left(\frac{f}{2}R\right)\Delta T$$

$$= 4\left(\frac{5}{2}\times R\right)(50) = 500R$$

58. (a) For adiabatic process

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

$$= \frac{100\times 4 - 200\times 3}{1.4-1} = -500\ \text{J}$$

59. (c) Given, number of mole, $n = 1$

$$W_{AB} = nRT\ln\frac{V_2}{V_1} = 1\times RT\ln\frac{2V_1}{V_1} = RT\ln 2$$

$$W_{BC} = 0$$

$$W_{CA} = \frac{P_1V_1 - P_2V_2}{\gamma-1} = \frac{\frac{P_1}{4}\times 2V_1 - P_1\times V_1}{\gamma-1}$$

$$\Rightarrow W_{CA} = \frac{\frac{P_1V_1}{2} - P_1V_1}{\gamma-1} = \frac{-P_1V_1}{2(\gamma-1)} = \frac{-1RT}{2(\gamma-1)}$$

$$\Rightarrow W_{CA} = \frac{-RT}{2(\gamma-1)}$$

$$\therefore W_{total} = W_{AB} + W_{BC} + W_{CA}$$

$$= RT\left[\ln 2 - \frac{1}{2(\gamma-1)}\right]$$

60. (b) $W_{AB} = nRT\ln\frac{2V_1}{V_1} = nRT\ln 2$

$$W_{BC} = P_2(V_1 - 2V_1) = -P_2V_1 = -\frac{1}{2}nRT$$

[$\because$ At B, $2P_2V_1 = nRT$]

As CA is isochoric process, $W_{CD} = 0$

$$W_{ABCD} = W_{AB} + W_{BC} + W_{CA}$$

$$= nRT\left(\ell n(2) - \frac{1}{2}\right)$$

61. [17258] Given, Temperature, T = 27°C = 300

$V_2 = 4m^3$, $V_1 = 2m^3$

Since process is isothermal, so

$$W = nRT\ell n\left(\frac{V_2}{V_1}\right) = 1\times 8.3\times 300\times \ell n\left(\frac{4}{2}\right)$$

$$= 1\times 8.3\times 300\times \ell n(2)$$

$$\Rightarrow W = 1\times 8.3\times 300\times 0.6931 \approx 1725.82\text{J}$$

$$\approx 17258\times 10^{-1}\text{J}$$

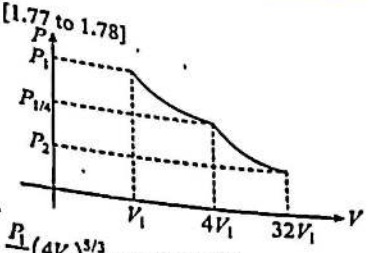
62. [50] $P = kV^3 \Rightarrow \frac{P}{V^3} = k \Rightarrow PV^{-3} = k$

$\Rightarrow$ Polytropic process with index $m = -3$

$$W = \frac{nR(T_2 - T_1)}{1-m} = \frac{nR(300-100)}{1-(-3)}$$

$$= 50\,nR.$$

63. [1.77 to 1.78]



$$\frac{P_1}{4}(4V_1)^{5/3} = P_2(32V_1)^{5/3}$$

$$P_2 = \frac{P_1}{4}\left(\frac{1}{8}\right)^{5/3} = \frac{P_1}{128}$$

$$W_{adi} = \frac{P_1V_1 - P_2V_2}{\gamma-1} = \frac{P_1V_1 - \frac{P_1}{128}(32V_1)}{\frac{5}{3}-1}$$

$$= \frac{P_1V_1(3/4)}{2/3} = \frac{9}{8}P_1V_1$$

$$W_{Iso} = P_1V_1\ln\left(\frac{4V_1}{V_1}\right) = 2P_1V_1\ln 2$$

$$\frac{W_{Iso}}{W_{adio}} = \frac{2P_1V_1\ln 2}{\frac{9}{8}P_1V_1} = \frac{16}{9}\ln 2 = f\ln 2$$

$$f = \frac{16}{9} = 1.7778 \approx 1.78$$

64. [2.05] $W = (\Delta P)_{ave}\times 4\pi R^2a$

$$= \left|\frac{dP}{2}.4\pi R^2a\right|$$

(for small change $(\Delta P)_{ave}$ <P> arithmetic mean)

$$= PV^\gamma = c \Rightarrow dP = -\gamma\frac{P}{V}dV = -\frac{\gamma P_0}{V}4\pi R^2a$$

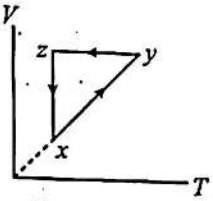
$$= \frac{\gamma P_0}{2V}\times 4\pi R^2a\times 4\pi R^2a$$

$$= \frac{\gamma P_0}{2\times 4\pi R^3}4\pi R^2a\times 4\pi R^2a$$

$$= \left(4pRP\times a^2\right)\frac{3\gamma}{2}$$

$$X \simeq 2.05$$

65. (a) V



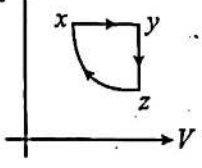
From the corresponding V-T graph

Process $xy \rightarrow$ Isobaric expansion,

Process $yz \rightarrow$ Isochoric (Pressure decreases)

Process $z-x \rightarrow$ Isothermal compression

Therefore, corresponding PV graph is



66. (d) For all process

$E_{AB} = E_{AC} = E_{AD}$

$W_{AB} > 0$

$W_{AC} = 0$

$W_{AD} < 0$

67. (a) PV^γ = constant

$$V \propto \frac{1}{\rho}$$

$$\frac{P}{\rho^\gamma} = \text{constant}$$

68. (a) $P_1 = 1$ atm, $T_1 = 273K$

$$P_1V_1^\gamma = P_2V_2^\gamma$$

$$P_2 = P_1\left[\frac{V_1}{V_2}\right]^\gamma = 1\ \text{atm}\left(\frac{1}{3}\right)^{1.4}$$

Now work done $\frac{P_1V_1 - P_2V_2}{\gamma-1} = 88.7\ J$

Closest answer is $90.5\ J$

69. (b) Relaxation time $(\tau)\propto\frac{V}{\sqrt{T}}$ and

$$T \propto \frac{1}{V^{\gamma-1}}$$

$$\tau \propto V^{1+\frac{1-\gamma}{2}}$$

$$\tau \propto V^{\frac{1+\gamma}{2}}$$

$$\frac{\tau_f}{\tau_i} = \left(\frac{2V}{V}\right)^{\frac{1+\gamma}{2}}$$

$$\frac{\tau_f}{\tau_i} = (2)^{\frac{1+\gamma}{2}}$$

70. (a) Here, ΔQ = heat supplied

ΔW = work done, ΔU = change in internal energy

A. adiabatic	II.	$\Delta Q = 0$
B. isothermal	IV.	$\Delta U = 0$
C. isochoric	I.	$\Delta W = 0$
D. isobaric	III.	$\Delta U \neq 0, \Delta W \neq 0, \Delta Q \neq 0$

71. (a) For process 3 – 1, volume is constant

$PV = nRT$; as P increases; T increases

For PV^γ = constant $\Rightarrow TV^{\gamma-1}$ = Constant

For process 2 – 3; pressure is constant

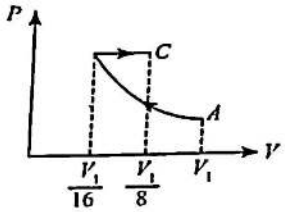
$V = kT$

72. (a) If the process is sodden, the energy can't be restored. Therefore the process will be irreversible adiabatic.

73. [1819] For process AB, PV^γ = constant, $TV^{\gamma-1}$ = constant

$$300(V_1)^{1.4-1} = T_B\left(\frac{V_1}{16}\right)^{0.4}$$

@FAKE_CBSE_X @RAJ_EDUNET



$T_B = 300 \times 2^{3/5}$

Now for BC process, pressure (P) is constant so

$\frac{V_B}{T_B} = \frac{V_C}{T_C}$

$T_C = \frac{V_C T_B}{V_B} = 2 \times 300 \times 2^{3/5}$

$T_C = 1818.859 \cong 1819$ K

74. [46] For adiabatic process $TV^{\gamma-1}$ = constant

$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1} = T_1 (10)^{\frac{7}{5}-1}$

$T_2 = T_1 (10)^{2/5} \approx 736$ K, Now $\Delta T = 443$ K

$\therefore \Delta U = N C_v \Delta T =$

$5 \times \frac{5}{2} \times 8.314 \times 443 = 46.03 \times 10^3$ J

$\Delta U = 46$ kJ

Hence, the value of X is 46.

75. (*d*) Process 1 → 2 is isothermal (temperature constant)

Process 2 → 3 is isochoric (volume constant)

A. Work done in 1 → 2 → 3

$W = W_{1\to2} + W_{2\to3}$

$= nRT \ln\left(\frac{V_f}{V_i}\right) + W_{2\to3}$

$= \frac{RT_0}{3} \ln\left(\frac{2V_0}{V_0}\right) + 0$

$W = \frac{RT_0}{3} \ln 2 \Rightarrow (P)$

B. ΔU in 1 → 2 → 3

$\Delta U = \frac{f}{2} nR(T_f - T_i) = \frac{3}{2} R\left(T_0 - \frac{T_0}{3}\right)$

$= \frac{3}{2} R\left(\frac{2T_0}{3}\right)$

$\Delta U = RT_0 \Rightarrow (R)$

C. For any system, first law of thermodynamics

for 1 → 2 → 3

$\Delta Q = \Delta U + W$

$\Delta Q = RT_0 + \frac{RT_0}{3} \ln 2$

$\Delta Q = \frac{RT_0}{3}(3 + \ln 2) \Rightarrow (T)$

D. For process 1 → 2 (isothermal)

$\Delta Q = \Delta U + W$

$= \frac{f}{2} nR(T_f - T_i) + nRT \ln (V_f/V_i)$

$= 0 + R\left(\frac{T_0}{3}\right) \ln\left(\frac{2V_0}{V_0}\right)$

$\Delta Q = \frac{RT_0}{3} \ln 2 \Rightarrow (P)$

76. (*c*) Suppose '*m*' gram of water evaporates then, heat required

$\Delta Q_{req} = mL_v$

Mass that converts into ice = $(150 - m)$

So, heat released in this process

$\Delta Q_{rel} = (150 - m) L_f$

Now, $\Delta Q_{rel} = \Delta Q_{req}$

$(150 - m) L_f = mL_v$

$m(L_f + L_v) = 150 L_f$

$m = \frac{150 L_f}{L_f + L_v} \Rightarrow m = 20$ g

77. (*c*) $w = nR\Delta T$

$\Delta H = (C_v + nR)\Delta T$

The ratio of work done to the heat supplied,

$\frac{w}{\Delta H} = \frac{nR}{C_v + nR}$

Hence, option (*c*) is correct answer.

78. (*b*) $\because TV^{(\gamma-1)}$ = constant

For dia atomic process $\gamma = 7/5$

$\gamma - 1 = \frac{7}{5} - 1 = \frac{2}{5}$

$\therefore x = \frac{2}{5}$

79. (*d*) Isochoric (constant volume) → Process *d*

Isobaric (constant pressure) → Process *a*

Isothermal (PV = constant) → Process *b*

Adiabatic (PV^γ = constant) → Process *c*

Adiabatic slope will be more than isothermal so order → *d a b c*

80. (*d*) Both A and R are true and R is the correct explanation of A

81. (*a*) Heat Transfer

A. By Newton's law of colling $\frac{d\theta}{dt} \propto \Delta T$

B. $H = \frac{d\theta}{dt} = \sigma e T^4 \Rightarrow \frac{H_P}{H_Q}$

$= \left(\frac{T_P}{T_Q}\right)^4 = \left(\frac{283}{293}\right)^4$

$H_P : H_Q = 1(1.03)^4 = 1 : (1.03)^4 = 1 : 1.15$

C. $\eta = 1 - \frac{100}{400} = \frac{3}{4} = 75\%$

D. is wrong as $\frac{d\theta}{dt} \propto \Delta T$

82. (*b*) $\eta = 1 - \frac{T_2}{T_1}$, so

$\frac{\eta_1}{\eta_2} = \frac{1 - \frac{T_{12}}{T_{11}}}{1 - \frac{T_{22}}{T_{21}}} = \frac{1 - \frac{T_{12}}{T_{11}}}{1 - \frac{T_{22}}{T_{21}}}$

$= \frac{1 - \frac{420}{720}}{1 - \frac{320}{1220}} = \frac{1 - 0.58}{1 - 0.26}$

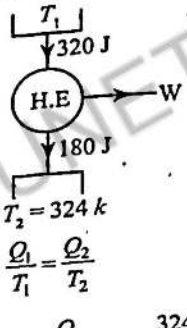
$\Rightarrow \frac{\eta_1}{\eta_2} = \frac{0.42}{0.74} \approx 0.56$

83. [31] Heat rejected = $mL + ms\Delta T$

$= (50 \times 540) + 50\,(1)\,(100 - 20)$

$= 31000$ Cal $= 31 \times 10^3$ Cal

84. [540] We know



$\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$

$T_1 = \frac{Q_1}{Q_2} \times T_2 = \frac{324 \times 300}{180} = 540K$

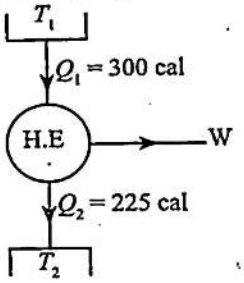
85. [102] We have given, $T_1 = 227°C$ = K, T_2 = ?

Using formula $\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$

$\Rightarrow \frac{300}{500} = \frac{225}{T_2}$

$\Rightarrow T_2 = \frac{500 \times 225}{300} = 375$ K = 102°C

Hence, temperature of sink will be 102°



86. (*d*) As we know, the efficiency of reversible engine is given by;

$\eta = 1 - \frac{T_2}{T_1}$ [T_2 → sink temperature]

@FAKE_CBSE_X@RAJ_EDUNET

$$\frac{1}{4}=1-\frac{T_2}{T_1}\ \&\ \frac{1}{2}=1-\frac{(T_2-58^\circ)}{T_1}$$

On comparing both equation, we get

$T_2 = 174°C$

87. (c)

Physical Quantity	Dimension
Entropy (S)	$[ML^2T^{-2}K^{-1}]$
Number of mole (μ)	mol
Mechanical equivalent of heat (J)	Dimensionless
Boltzmann constant (k)	$[ML^2T^{-2}K^{-1}]$
Gas constant (R)	$[ML^2T^{-2}K^{-1}]$

$\beta^2 \equiv [\mu kR] \Rightarrow \beta^2 \equiv [kR] \Rightarrow \beta \equiv [k] \equiv [ML^2T^{-2}K^{-1}]$, and

$S \equiv \alpha^2\beta \Rightarrow [ML^2T^{-2}K^{-1}] \equiv \alpha^2 [ML^2T^{-2}K^{-1}]$

$\Rightarrow \alpha \equiv [M^0L^2T^0K^0] \Rightarrow$ *Dimensionless*

88. (d) $S = S_1 + S_2$

89. (b) Given, $\eta = \frac{1}{6}$ let temp. of sink be T_c and temp of source be T_H.

$\therefore \frac{1}{6} = 1 - \frac{T_c}{T_{CH}}$ ... (i)

$\frac{1}{3} = 1 - \frac{T_c - 62}{T_H}$ ... (ii)

By (i) and (ii)

$\frac{62}{T_H} = \frac{1}{3} - \frac{1}{6} = \frac{1}{6}$

$T_H = 62 \times 6 = 372K = 99°C$

90. [500] $1 - \frac{T_2}{T_1} = \frac{W}{Q}$

$\Rightarrow 1 - \frac{400}{T_1} = \frac{300-240}{300} = \frac{1}{5}$

$\Rightarrow \frac{4}{5} = \frac{400}{T_1}$

$\therefore T_1 = 500K$

91. [208] $\eta = \frac{\text{work}}{\text{heat}} = \frac{1}{4}$

Also, $\eta = 1 - \frac{T_c}{T_h}, 2n = 1 - \frac{T_c - 52}{T_h}$

$\Rightarrow T_h = 208$ K

92. (d) It is given that, TH = 25°C = 298 K, TL = –10°C = 263 K.

$\therefore \frac{Q_H}{Q_L} = \frac{T_H}{T_L}$

$\Rightarrow Q_L = \frac{T_L}{T_H - T_L} \times (Q_H - Q_L)$

$\Rightarrow \frac{dQ_L}{dt} = \frac{T_L}{T_H - T_L} \cdot \frac{d(Q_H - Q_L)}{dt}$

$= \frac{263}{35} \times 35 = 263$ Js^{-1}

93. (d) Efficiency (η) of an heat engine

$= \frac{Q_{net}}{\Sigma Q_+}$

$\Rightarrow \frac{50}{100} = \frac{1915 - 40 + 125 - Q}{1915 + 125} \Rightarrow \frac{1}{2}$

$= \frac{2000 - Q}{2040}$

$\Rightarrow 1020 = 2000 - Q$

$\Rightarrow Q = 980$ J

94. [8791] Heat absorbed

$Q_2 = mL = 100 \text{ gm} \times \frac{80 \text{ cal}}{\text{gm}} = 8000$ cal

$\frac{Q_1}{T_1} = \frac{Q_2}{T_2} \Rightarrow Q_1 = \frac{8000 \times 300}{273} = 8791$ cal

95. [19] $W = 2P_0V_0$

$Q_+ = 2P_0V_0 \times \frac{3}{2} + \frac{5}{2} \times 3P_0V_0$

$\eta = \frac{2P_0V_0}{3P_0V_0 + \frac{15}{2}P_0V_0} = \frac{4}{21}$

$\eta = 19.04\%$

JEE-Advanced

1. (b, c) There is a decrease in volume during melting of an ice slab at 273 K. Therefore, negative work is done by ice-water system on the atmosphere or positive work is done on the ice-water system by the atmosphere. Hence, option (b) is correct. Secondly heat is absorbed during melting (i.e., Q is positive) and as we have seen, work done by ice-water system is negative (W is negative). Therefore, from first law of thermodynamics $\Delta U = Q - W$ change in internal energy of ice-water system, ΔU will be positive or internal energy will increase.

2. [2] $W_{ibf} = W_{ib} + W_{bf} = 50$ J + 100 J = 150 J

$W_{iaf} = W_{ia} + W_{af} = 0$ J + 200 J = 200 J

$Q_{iaf} = 500$ J

So $\Delta U_{iaf} = Q_{iaf} - W_{iaf} = 500$ J – 200 J = 300 J = $U_f - U_i$

So, $U_f = U_{iaf} + U_i = 300$ J + 100 J = 400 J

$\Delta U_{ib} = U_b - U_i = 200$ J – 100 J = 100 J

$Q_{ib} = \Delta U_{ib} + W_{ib} = 100$ J + 50 J = 150 J

$Q_{ibf} = \Delta U_{ibf} + W_{ibf} = \Delta U_{iaf} + W_{ibf}$

= 300 J + 150 J = 450 J

So, the required ratio

$\frac{Q_{bf}}{Q_{ib}} = \frac{Q_{ibf} - Q_{ib}}{Q_{ib}} = \frac{450 - 150}{150} = 2$

3. [–972] In adiabatic process

$p_iV_i^\gamma = p_fV_f^\gamma$

$p_f = \left(\frac{V_i}{V_f}\right)^\gamma p_i$ ...(i)

Further, $C_V = \frac{3R}{2}$

$\therefore C_p = C_V + R = \frac{5R}{2}$ or $\gamma = \frac{C_p}{C_V} = \frac{5}{3}$

$\therefore p_f = \left(\frac{6}{2}\right)^{\frac{5}{3}} (10)^5 = 6.24 \times 10^5$ N/m^2

Now, work done in adiabatic process is given by

$W = \frac{p_iV_i - p_fV_f}{\gamma - 1}$

$= \frac{10^5 \times 6 \times 10^{-3} - 6.24 \times 10^5 \times 2 \times 10^{-3}}{\left(\frac{5}{3}\right) - 1}$

= –972 J

NOTE Work done is negative because volume of the gas is decreasing.

4. Ideal diatomic gas is enclosed in an insulated of the gas

$T_1 = 300\ K\ T_2 = 400\ K$

$h_1 = 1m \qquad h_2 = ?$

where T_1 = initial temperature and T_2 = final temperature

$\frac{PV_1}{T_1} = \frac{PV_2}{T_2}$

$\frac{h_1A}{T_1} = \frac{h_2A}{T_2}$

$\Rightarrow h_2 = \frac{T_2h_1}{T_1} = \frac{400}{300}h_1 = \frac{4}{3}h_1$

$\Rightarrow h = \frac{4}{3}m$

CLEAR_CBSE_X @RAJ_EDUNET

Now in adiabatic process

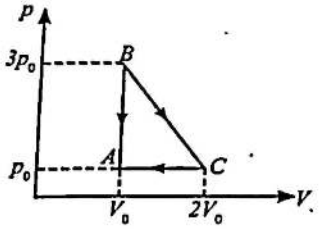
$$r=\frac{C_p}{C_v}=\frac{\frac{7}{2}R}{\frac{5}{2}R}=\frac{7}{5}$$

$$T_2=T_1\left(\frac{V_1}{V_2}\right)^{r-1}$$

$$T_2=T_1\left(\frac{h_1}{h_2}\right)^{r-1}=400\left(\frac{4/3}{1}\right)^{\frac{7}{5}-1}$$

$$T_2=400\left(\frac{4}{3}\right)^{\frac{2}{5}}K$$

5. (a) $ABCA$ is a clockwise cyclic process.



∴ Work done by the gas
W = + Area of triangle ABC

$$=\frac{1}{2}(\text{base})(\text{height})$$

$$=\frac{1}{2}(2V_0-V_0)(3p_0-p_0)$$

$$W=p_0V_0$$

(b) Number of moles $n = 1$ and gas is mono-atomic, therefore

$$C_V=\frac{3}{2}R \text{ and } C_p=\frac{5}{2}R$$

$$\Rightarrow \frac{C_V}{R}=\frac{3}{2} \text{ and } \frac{C_p}{R}=\frac{5}{2}$$

(i) Heat rejected in path CA (Process is isobaric)

$$Q_{CA}=C_p\Delta T=C_p(T_f-T_i)$$

$$=C_p\left(\frac{p_fV_f}{R}-\frac{p_iV_i}{R}\right)$$

$$=\frac{C_p}{R}(p_fV_f-p_iV_i)$$

Substituting the values

$$Q_{CA}=\frac{5}{2}(p_0V_0-2p_0V_0)=-\frac{5}{2}p_0V_0$$

Therefore, heat rejected in the process CA is $\frac{5}{2}p_0V_0$.

(ii) Heat absorbed in path AB (Process is isochoric)

$$Q_{AB}=C_V\Delta T=C_V(T_f-T_i)$$

$$=C_V\left(\frac{p_fV_f}{R}-\frac{p_iV_i}{R}\right)$$

$$=\frac{C_V}{R}(p_fV_f-p_iV_i)$$

$$=\frac{3}{2}(p_fV_f-p_iV_i)$$

$$=\frac{3}{2}(3p_0V_0-p_0V_0)$$

$$Q_{AB}=3p_0V_0$$

∴ Heat absorbed in the process AB is $3p_0V_0$.

(c) Let Q_{BC} be the heat absorbed in the process BC:

Total heat absorbed,

$$Q=Q_{CA}+Q_{AB}+Q_{BC}$$

$$Q=\left(-\frac{5}{2}p_0V_0\right)+(3p_0V_0)+dQ_{BC}$$

$$Q=Q_{BC}+\frac{p_0V_0}{2}$$

Change in internal energy, $\Delta U = 0$

$$\therefore Q=W$$

$$Q_{BC}+\frac{p_0V_0}{2}=p_0V_0$$

$$Q_{BC}=\frac{p_0V_0}{2}$$

∴ Heat absorbed in the process BC is $\frac{p_0V_0}{2}$.

(d) Maximum temperature of the gas will be somewhere between B and C. Line BC is a straight line. Therefore, $p - V$ equation for the process BC can be written as

$$p=-mV+c \qquad (y=mx+c)$$

Here, $m=\frac{2p_0}{V_0}$ and $c=5p_0$

$$\therefore p=-\left(\frac{2p_0}{V_0}\right)V+5p_0$$

Multiplying the equation by V,

$$pV=-\left(\frac{2p_0}{V_0}\right)V^2+5p_0V$$

$$(pV=RT \text{ for } n=1)$$

$$RT=-\left(\frac{2p_0}{V_0}\right)V^2+5p_0V$$

$$\text{or } T=\frac{1}{R}\left[5p_0V-\frac{2p_0}{V_0}V^2\right]$$

For T to be maximum, $\frac{dT}{dV}=0$

$$\Rightarrow 5p_0-\frac{4p_0}{V_0}V=0\Rightarrow V=\frac{5V_0}{4}$$

i.e. at $V=\frac{5V_0}{4}$, (on line BC), temperature of the gas is maximum. This maximum temperature will be

$$T_{max}=\frac{1}{R}\left[5p_0\left(\frac{5V_0}{4}\right)-\frac{2p_0}{V_0}\left(\frac{5V_0}{4}\right)^2\right]$$

$$T_{max}=\frac{25}{8}\frac{p_0V_0}{R}$$

6. (b)

(a) $\Delta U=\Delta Q-\Delta W$

$$=\left\{\left(10^{-3}\times2250\right)-\frac{10^5\left(10^{-3}-10^{-4}\right)}{10^3}\right\}\text{kJ}$$

$$=(2.25-0.00999)\text{ kJ}=(2.1501)\text{ kJ}$$

(b) $U=nC_V\Delta T=\frac{5}{2}nR\Delta T$

$$=\frac{5}{2}\cdot(0.2)(8)(1500-500)\text{J}=4\text{kJ}$$

(c) $P_1V_2^\gamma=P_2V_2^\gamma$

$$\Rightarrow 2\left(\frac{1}{3}\right)^{5/3}=P_2\left(\frac{1}{24}\right)^{5/3}$$

$$\Rightarrow P_2=64\text{kPa}$$

$$\Delta U=nC_v\Delta T=\frac{3}{2}\cdot(P_2V_2-P_1V_1)$$

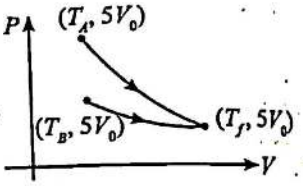
$$=\frac{3}{2}\left(64\times\frac{1}{24}-2\times\frac{1}{3}\right)\text{kJ}=3\text{kJ}$$

(d) $\Delta U=nC_V\Delta T$

$$=n\cdot\frac{7}{2}R\Delta T=\frac{7}{9}\Delta Q=7\text{ kJ}$$

7. (b)

8. (a)

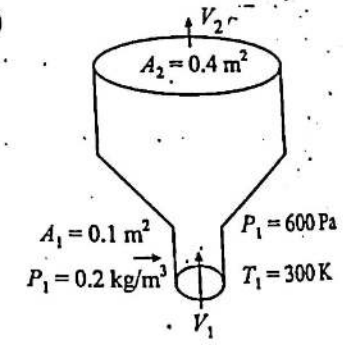


For adiabatic, $TV^{\gamma-1}=$ constant.

$$\therefore T_AV_0^{\gamma-1}=T_f(5V_0)^{\gamma-1}$$

$$\frac{T_A}{T_f}=5^{\gamma-1}=\frac{T_A}{T_B}$$

9. (b)



@TIKE_CBSE_KORAJ_EDU.NET

$\frac{dm}{dt} = \rho_1 A_1 V_1 = 0.8\,\text{kg/s}$

or $V_1 = \frac{0.8}{0.2 \times 0.1} = 40\,\text{m/s}$

$g = 10\,\text{m/s}^2$

$\gamma = 2$, $P^{1-\gamma} T^{\gamma} = \text{constant}$

Gas undergoes adiabatic expansion,

$$\frac{P_2}{P_1} = \left(\frac{T_1}{T_2}\right)^{\frac{\gamma}{1-\gamma}}$$

$$P_2 = \left(\frac{300}{150}\right)^{\frac{2}{-1}} \times 600$$

$$P_2 = \frac{600}{4} = 150\,\text{Pa}$$

or $\rho = \frac{PM}{RT} \Rightarrow \rho \propto \frac{P}{T}$

$$\frac{\rho_1}{\rho_2} = \left(\frac{P_1}{P_2}\right)\left(\frac{T_2}{T_1}\right)$$

$$= \left(\frac{150}{600}\right)\left(\frac{300}{150}\right) = \frac{1}{2}$$

$$\rho_2 = \frac{\rho_1}{2} = 0.1\,\text{kg/m}^3$$

Now, $\rho_2 A_2 V_2 = 0.8 \Rightarrow V_2 = \frac{0.8}{0.1 \times 0.4}$

$= 20$ m/s

Now work done W on gas $= \Delta K + \Delta U$ + Internal energy

$P_1 A_1 \Delta x_1 - P_2 A_2 \Delta x_2$

$$= \frac{1}{2}\Delta m V_2^2 - \frac{1}{2}\Delta m V_1^2 + \Delta mgh + \frac{f}{2}\left(P_2 \Delta V_2 - P_1 \Delta V_1\right)$$

$$\Rightarrow 2P_1 \frac{\Delta V_1}{\Delta m} - 2P_2 \frac{\Delta V_2}{\Delta m}$$

$$= \frac{V_2^2 - V_1^2}{2} + gh$$

$$\Rightarrow \frac{2 \times 600}{0.2} - \frac{2 \times 150}{0.1}$$

$$= \frac{20^2 - 40^2}{2} + 10h$$

$h = 360$ m

10. (*d*) For isobaric processes.

$\Delta Q = nC_P \Delta T$

$$= 2 \times \frac{5}{2} R \times (35 - 30) = 208\,\text{J}$$

11. (*c*) $pT^2 = \text{constant}$

$\therefore \left(\frac{nRT}{V}\right) T^2$ constant

or $T^3 V^{-1} = \text{constant}$

On Differentiating the above equation, we get $\frac{3T^2}{V} \cdot dT - \frac{T^3}{V^2} dV = 0$

or $3dT = \frac{T}{V} \cdot dv$ ...(*i*)

By the equation, $dV = V\gamma dT$

γ = coefficient of volume expansion of gas $= \frac{dV}{V \cdot dt}$

From Equation (*i*) $\gamma = \frac{dV}{V \cdot dt} = \frac{3}{T}$

12. (*c*) For the same phase temperature of liquid oxygen will first increase. So, the temperature will remain the same when the liquid oxygen will change to gaseous phase. After that, the temperature of oxygen gets increased in gaseous state.

13. (*b*) $A - B$ is an isothermal process.

$B - C$ is an isobaric process.

$A - C$ is an adiabatic process.

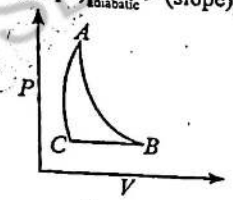
Therefore the $P - V$ diagram will be

for A to B, PV= constant

for B to C, P = constant

for A to C, PV^{γ} = constant, work done in isothermal process is more then the adiabatic process

$(\text{slope})_{\text{adiabatic}} > (\text{slope})_{\text{isothermal}}$



14. (*a*) According to ideal gas equation

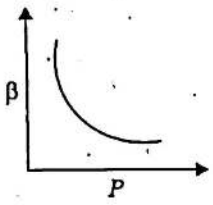
$\because PV = nRT$

At constant T, by differentiation

$P \cdot dV + V \cdot dP = 0$

or $\left[\frac{dV}{dP}\right]_T = -\frac{V}{P}$

or $\beta = -\frac{\left[\frac{dV}{dP}\right]_T}{V} = \frac{1}{P}$



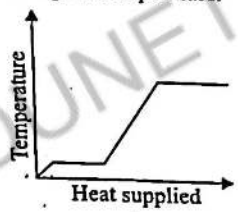
15. (*a*) Initially ice is at $T = -10°C$. When it is heated,

(*i*) Ice at $-10°C$ changes to ice at $0°C$. Thus in this the temperature of change rises with the supply of heat.

(*ii*) Next ice at $0°C$ changes to water at $0°C$. Thus in this process there is change in phase with no change in temperature. Temperature is constant.

(*iii*) Water at $0°C$ changes to water at $100°C$. Thus there is rise in temperature.

(*iv*) Water at $100°C$ changes to steam at $100°C$. This results in phase change from liquid to gas without any change in temperature.



16. (*c*) We know that V / T = constant; at constant pressure

$\frac{V + \Delta V}{T + \Delta T} = \frac{V}{T}$

or $VT + T\Delta V = VT + V\Delta T$

Or $T\Delta V = V\Delta T$ or $\frac{\Delta V}{V\Delta T} = \frac{1}{T}$

17. (*c*) Process is isothermal. Therefore, T = constant. $\left(p \propto \frac{1}{V}\right)$ volume is increasing, therefore, pressure will decrease.

In chamber $A \rightarrow$

$$-\Delta p = (p_A)_i - (p_A)_f = \frac{n_A RT}{V} - \frac{n_A RT}{2V}$$

$$= \frac{n_A RT}{2V} \quad \text{...(i)}$$

In chamber $B \rightarrow$

$$-1.5\Delta p = (p_B)_i - (p_B)_f = \frac{n_B RT}{V} - \frac{n_B RT}{2V}$$

$$= \frac{n_B RT}{2V} \quad \text{...(ii)}$$

From Eqn. (*i*) and (*ii*)

$\frac{n_A}{n_B} = \frac{1}{1.5} = \frac{2}{3}$ or $\frac{m_A / M}{m_B / M} = \frac{2}{3}$

$\frac{m_A}{m_B} = \frac{2}{3}$ or $3m_A = 2m_B$

@FAKE_CBSE_ORAL_EDUNET

18. (b,c,d) For adiabatic process $(A \to B)$

$$P_A V_A^{\gamma} = P_B V_B^{\gamma}$$

$$10^5 \times (0.8)^{\frac{5}{3}} = 3 \times 10^5 (V_B)^{\frac{5}{3}}$$

$$\Rightarrow V_B = 0.8 \times \left(\frac{1}{3}\right)^{0.6} = 0.4$$

Work done in process $A \to B$

$$W_{AB} = \frac{P_A V_A - P_B V_B}{\gamma - 1}$$

$\Rightarrow W_{AB} = 0.60$ kJ $\Rightarrow |W_{AB}| = 60$ kJ

Work done $B \to C$ in process (Isothermal process)

$$W_{BC} = nRT\ell n\frac{V_C}{V_B} = P_B V_B \ell n\frac{V_C}{V_B}$$

$$\Rightarrow W_{BC} = 3 \times 10^5 \times 0.4 \ell n\frac{0.8}{0.4}$$

$\Rightarrow W_{BC} = 84$ kJ

Work done in process $C \to A$

$W_{CA} = P\Delta V = 0 \quad (\because V = 0)$

So total work done in the process

$A \to B \to C$

$W_{ABC} = W_{AB} + W_{BC} + W_{CA}$

$= 60 + 84 + 0$

$W_{ABC} = 24$ kJ

19. (a, c)

$$\left|\Delta Q_{(1\to 2)}\right| = nC_p dT = n \times \frac{5}{2} R \times T_0 = \frac{5RT_0}{2}$$

$$\left|\Delta Q_{3\to 4}\right| = nC_p dT = n \times \frac{5}{2} R \frac{T_0}{2} = \frac{5RT_0}{4}$$

$$\frac{\left|\Delta Q_{1\to 2}\right|}{\left|\Delta Q_{3\to 4}\right|} = 2 \text{ Also } \left|\Delta Q_{2\to 3}\right| = \frac{3}{2} RT_0$$

$$\frac{(\Delta Q_{1\to 2})}{(\Delta Q_{2\to 3})} = \frac{5RT_0 \times 2}{2 \times 3RT_0} = \frac{5}{3}$$

$$w = \Sigma \Delta Q = \frac{RT_0}{2}$$

20. (b, c, d) Process-II is isothermal expansion,

$\Delta U = 0, W > 0$

$\Delta Q = W > 0$

Process-IV is isothermal compression,

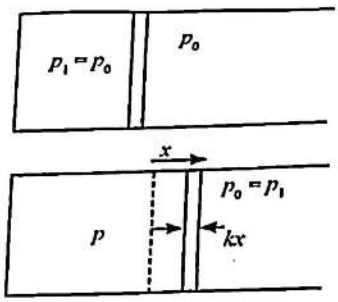
$\Delta U = 0, W < 0$

$\Delta Q = W < 0$

Process-I and III are not isobaric because in isobaric process $T \propto V$ hence, $T - V$ graph should be a straight line passing through origin.

Options b, c and d are true.

21. (a, b, c) NOTE: This question can be solved if right hand side chamber is assumed to be open, so that its pressure remains constant.



(a) $pV = nRT \Rightarrow p \propto \frac{T}{V}$

Temperature is made three times and volume is doubled.

$$\Rightarrow p_2 = \frac{3}{2} p_1$$

Further $x = \frac{\Delta V}{A} = \frac{V_2 - V_1}{A}$

$$= \frac{2V_1 - V_1}{A} = \frac{V_1}{A}$$

$$p_2 = \frac{3p_1}{2} = p_1 + \frac{kx}{A} \Rightarrow kx = \frac{p_1 A}{2}$$

Energy of spring

$$\frac{1}{2} kx^2 = \frac{p_1 A}{4} x = \frac{p_1 V_1}{4}$$

(b) $\Delta U = nc_v \Delta T = n\left(\frac{3}{2} R\right)\Delta T$

$$= \frac{3}{2}(p_2 V_2 - p_1 V_1)$$

$$= \frac{3}{2}\left[\left(\frac{3}{2} p_1\right)(2V_1) - p_1 V_1\right] = 3p_1 V_1$$

(c) $p_2 = \frac{4p_1}{3}$

$$\Rightarrow p_2 = \frac{4}{3} p_1 = p_1 + \frac{kx}{A}$$

$$\Rightarrow kx = \frac{p_1 A}{3} \Rightarrow x = \frac{\Delta V}{A} = \frac{2V_1}{A}$$

$W_{gas} = (p_0 \Delta V + W_{spring})$

$$= \left(p_1 Ax + \frac{1}{2} kx \cdot x\right)$$

$$= +\left(p_1 A \cdot \frac{2V_1}{A} + \frac{1}{2} \cdot \frac{p_1 A}{3} \cdot \frac{2V_1}{A}\right)$$

$$= 2p_1 V_1 + \frac{p_1 V_1}{3} = \frac{7p_1 V_1}{3}$$

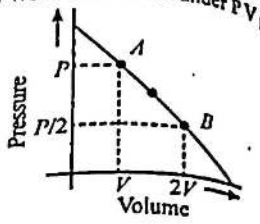
(d) $\Delta Q = W + \Delta U$

$$= \frac{7p_1 V_1}{3} + \frac{3}{2}(p_2 V_2 - p_1 V_1)$$

$$= \frac{7p_1 V_1}{3} + \frac{3}{2}\left(\frac{4}{3} p_1 \cdot 3V_1 - p_1 V_1\right)$$

$$= \frac{7p_1 V_1}{3} + \frac{9}{2} p_1 V_1 = \frac{41 p_1 V_1}{6}$$

22. (a, b, d) Work done Area under P V diagram



$A_1 > A_2$

$\therefore W_{\text{given process}} > W_{\text{Isothermal process}}$

Thus (A) is correct.

In the given process $P - V$ equation will be a straight line with negative slope and positive intercept, i.e.,

$P = -aV + b$

Here, a and b are positive constants.

$P = -aV + b$

$\Rightarrow PV = -aV^2 + bV$

$\Rightarrow nRT = -aV^2 + bV$

$[\because PV = nRT$ (From ideal gas equation)]

$$\Rightarrow T = \frac{1}{\pi R}(-aV^2 + bV)$$

The above equation is of parabola.

Thus (B) is correct.

$$T = \frac{1}{\pi R}(-aV^2 + bV)$$

$$\frac{dT}{dV} = 0$$

$$\Rightarrow \frac{1}{\pi R}(-2aV + b) = 0$$

$$\Rightarrow -2aV + b = 0$$

$$\Rightarrow V = \frac{b}{2a}$$

Now

$$\frac{d^2 T}{dV^2} = -2a = -ve$$

Therefore T has some maximum value.

Now, from ideal gas equation,

$T \propto PV$

$\because (PV)_A = (PV)_B$

$\therefore T_A = T_B$

We conclude that temperatures are the same at A and B but in between the temperature has a maximum value.

Hence in going from A to B, the temperature will first increase to a maximum value and then decrease.

Thus (D) is correct.

23. (c)

24. (b)

25. (b)

26. (a)

27. (b)

28. (a)

@FAKE_CBSE_X_ORAJ_BOUNET

24. (c) $v_{sound} = \sqrt{\frac{\gamma RT}{M}}$ As the sound wave propagates, adiabatically the air in a chamber undergoes compression and rarefaction very fastly, hence undergo a adiabatic process. So, curves are steeper than isothermal.

$$\left(\frac{dp}{dV}\right)_{Adi} = -\gamma\left(\frac{p}{V}\right) \quad ...(i)$$

$$\left(\frac{dp}{dV}\right)_{Iso} = -\left(\frac{p}{V}\right) \quad ...(ii)$$

Graph 'Q' satisfies Eq. (i)

25. (b) $\Delta U = \Delta Q - p\Delta V$

$\Delta U + p\Delta V = \Delta Q$

As $\Delta U \neq 0, W \neq 0, \Delta Q \neq 0$. The process represents, isobaric process

$W_{gas} = -p(\Delta V) = -p(V_2 - V_1) = -pV_2 + pV_1$

Graph 'P' satisfies isobaric process.

26. (b) Work done in isochoric process is zero.

$W_{12} = 0$ as $\Delta V = 0$

Graph 'S' represents isochoric process.

27. (a) $g = \frac{3}{2}$

$$T_0 V_0^{\frac{3}{2}-1} = T_R \times \left(\frac{V_0}{2}\right)^{\frac{3}{2}-1}$$

$$\frac{T_R}{T_0} = \sqrt{2}$$

28. (b) $Q = \Delta U = \Delta U_1 + \Delta U_2$

For ΔU_2 : Using mole conservation of left side.

$$\frac{p_0 V_0}{RT_0} = \frac{2\sqrt{2}p_0 \frac{3V_0}{2}}{RT_L} \Rightarrow T_L = 3\sqrt{2}T_0$$

$$\Delta U_1 = 1 \times 2R \times \left(3\sqrt{2}T_0 - T_0\right)$$

$$= 2RT_0\left(3\sqrt{2} - 1\right)$$

$$Q = 2RT_0(\sqrt{2} - 1) + 2RT_0(3\sqrt{2} - 1)$$

$$= 2RT_0(4\sqrt{2} - 2)$$

$$\frac{\Delta R}{RT_0} = 4(2\sqrt{2} - 1)$$

29. (a) $W_{1\to2\to3} = W_{1\to2} + W_{2\to3}$

$$= R\frac{T_0}{3}\ln\frac{2V_0}{V_0} + 0 = \frac{RT_0}{3}\ln 2$$

$$\Delta U_{1\to2\to3} = \Delta U_{1\to2} + \Delta U_{2\to3}$$

$$= 0 + nC_V\left(T_0 - \frac{T_0}{3}\right)$$

$$= 0 + 1 \times \frac{3R}{2} \times \frac{2T_0}{3} = RT_0$$

$$\Delta Q_{1\to2} = \int T dx = \int T\left(\frac{3R}{2T}dT + \frac{R}{2}dV\right)$$

$$= \frac{3R}{2}\int dT + \int_{V_0}^{2V_0}\frac{RT}{V}dV = 0 + RT\ln 2$$

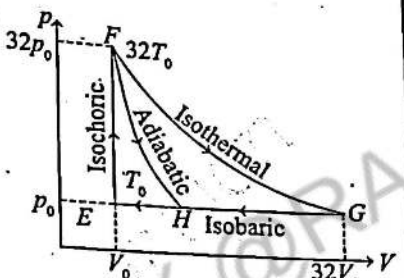
$$\Delta Q_{2\to3} = \int T dx = \frac{3R}{2}\int_{T_0/3}^{T_0} dT + \int\frac{RT}{V}dV$$

$$= \frac{3R}{2} \times \frac{2T_0}{3} + 0 = RT_0$$

$$\Delta Q_{1\to2\to3} = RT\ln 2 + RT_0$$

$$= \frac{1}{3}RT_0(3 + \ln 2)$$

30. (a)



In $F - G$ process:

T = constant

$$V \propto \frac{1}{P} \Rightarrow P_G = \frac{P_F}{32}$$

$\therefore V_G = 32\,V_F = 32\,V_0$

In $F \to G$ work done in isothermal process is $nRT\ln\left(\frac{V_f}{V_i}\right)$

$$= 32\,p_0V_0\ln\left(\frac{32V_0}{V_0}\right)$$

$= 32\,p_0V_0\ln 2^5 = 160p_0\,V_0\ln 2$

In G$\to E$, $\Delta W = p_0\Delta V = p_0(31V_0)$

$= 31p_0V_0$

In $G \to H$ work done is less than $31\,p_0V_0$ i.e. $24\,p_0V_0$

In $F \to H$ work done is $36\,p_0V_0$

31. (A) $\to(p, r, t)$; (B) $\to(p, r)$; (C) $\to(q, s)$; (D) $\to(r, t)$

Internal energy $\propto T \propto pV$

This is because $U = \frac{nf}{2}RT = \frac{f}{2}(pV)$

Here, n = number of moles, f = degree of freedom.

$\therefore$ If the product pV increases then internal energy will increase and if product decreases the internal energy will decrease.

Further, work is done on the gas, if volume of gas decreases. For heat exchange,

$Q = W + \Delta U$

Work done is area under $p - V$ graph. If volume increases work done by gas is positive and if volume decreases work done by gas is negative. Further ΔU is positive if product of pV is increasing and ΔU is negative if product of pV is decreasing.

If heat is taken by the gas Q is positive and if heat is lost by the gas Q is negative. Keeping the above points in mind the answer to this question is as under.

32. (c) As the pressure is reduced and the volume is increased, the system's temperature should remain constant because container is insulated, satisfying.

$PV = nRT$

As, $P \propto \frac{1}{V^2}$, $\therefore n = 2$, (Given)

$PV^2 = $ Constant

$$\left(\frac{nRT}{V}\right)V^2 = C$$

$$\therefore T \propto \frac{1}{V}$$

Also, for polytropic process

$$C = C_V + \frac{R}{1-n}$$

For mono-atomic gas

$$C_V = \frac{f}{2}R = \frac{3}{2}R$$

C$\to$ (+ve)

Using $Q = nC\Delta T$

Q –ve {Heat is lost since, $\Delta T = -ve$}

(c) Given $P \propto \frac{1}{V^{4/3}}$, $n = 4/3$(Given)

$\therefore PV^{4/3} = C$

$$\left(\frac{nRT}{V}\right)V^{4/3} = C$$

$T \propto \frac{1}{V^{1/3}}$, for polytropic process

$C = C_V + \frac{R}{1-n}$ $C = -3/2R$

Using $Q = nC\Delta T$, Q (+ve)

($\therefore \Delta T$(–ve), Heat is gain

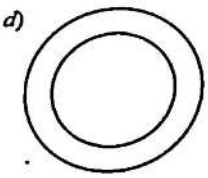
@TAKE_CBSE_V @RAJ_EDUNET

Area under PV curve i.e. PV is directly proportional to temperature [using ideal gas equation]

Also area under PV curve gives work done which is positive since volume is increasing. This also implies temperature is increasing.

Therefore, by first law of thermodynamics we can say heat is positive i.e. heat is gained by system.

33. (c, d)



$$P_{gas} = P_a + \frac{4S}{r}$$

$PV\gamma$ = constant [adiabatic process]

$$\left(Pa_1 + \frac{4S}{r_1}\right)\left(\frac{4}{3}\pi r_1^3\right)^{5/3}$$

$$= \frac{4P}{\beta^4 T_0^4}[T(t) - T_0]^3$$

$$\frac{r_1^3}{r_2^3} = \left(\frac{P_{a_2} + \frac{4S}{r_2}}{P_{a_1} + \frac{4S}{r_1}}\right)$$

$p^{1-\gamma}T^{\gamma}$ = constant

$$\left(P_{a_2} + \frac{4S}{r_2}\right)^{1-5/3} T_2^{5/3}$$

$$= \left(P_{a_1} + \frac{4S}{r_1}\right)^{1-5/3} T_1^{5/3}$$

$$\left(\frac{T_2}{T_1}\right)^{5/3} = \left(\frac{P_{a_1} + \frac{4S}{r_1}}{P_{a_2} + \frac{4S}{r_2}}\right)^{-2/3}$$

$$\left(\frac{T_2}{T_1}\right)^{5/2} = \left(\frac{P_{a_2} + \frac{4S}{r_2}}{P_{a_1} + \frac{4S}{r_1}}\right)$$

d is correct.

34. (a,c,d) $\gamma_{mixture} = \dfrac{5\times\frac{5R}{2} + \frac{7R}{2}}{5\times\frac{3R}{2} + 1\times\frac{5R}{2}} = \dfrac{8}{5} = 1.6$

For adiabatic process

PV^{γ} = const.

$$\therefore P = P_0\left(\frac{V_0}{V}\right)^{\gamma} = (4)^{8/5}.P_0 = 9.2P_0$$

$$\therefore W = \frac{P_0V_0 - 9.2P_0\frac{V_0}{4}}{\gamma - 1} = \frac{-13P_0V_0}{6}$$

As we know $P_0V_0 = 6RT_0$

$\therefore W = -13RT_0$

Final temp. after compression

$$T = T_0\left(\frac{PV}{P_0V_0}\right) = 2.3T_0$$

Also, $(C_V)_{mixture}$

$$= \frac{n_1C_{V_1} + n_2C_{V_2}}{n_1 + n_2} = \frac{5R}{3}$$

Average KE of gas

$= U_f = nC_VT$

$$= 6\times\frac{5R}{3}\times 2.3T_0 = 23RT_0$$

35. [900] Given, $n = 1, \gamma = \dfrac{5}{3}$

$T - V$ equation in adiabatic process is

$TV^{\gamma-1}$ = constant

$\therefore T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$$\Rightarrow T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = 100\times\left(\frac{1}{8}\right)^{\frac{2}{3}}$$

$\Rightarrow T_2 = 25$ K

$C_V = \dfrac{3}{2}R$ for mono-atomic gas

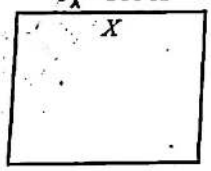
$$\therefore \Delta U = nC_V\Delta T = n\times\left(\frac{3R}{2}\right)(T_2 - T_1)$$

$$= 1\times\frac{3}{2}\times 8\times(25-100) = -900\text{ J}$$

$\therefore$ Decrease in internal energy = 900J

36. In the first part of the question ($t \le t_1$)

$T_A = 300$ K



At $t = 0$, $T_X = T_0 = 400$K and at $t = t_1$, $T_x = T_1 = 350$ K

Temperature of atmosphere, $T_A = 300$ K (constant)

This cools down according to Newton's law of cooling. Therefore, rate of cooling$\propto$ temperature difference.

$$\therefore \left(-\frac{dT}{dt}\right) = k(T - T_A)$$

$$\Rightarrow \frac{dT}{T - T_A} = -kdt$$

$$\Rightarrow \int_{T_0}^{T_1}\frac{dT}{T - T_A} = -k\int_0^{t_1}dt$$

$$\Rightarrow \ln\left(\frac{T_1 - T_A}{T_0 - T_A}\right) = -kt_1$$

$$\Rightarrow kt_1 = -\ln\left(\frac{350-300}{400-300}\right)$$

$\Rightarrow kt_1 = \ln(2)$

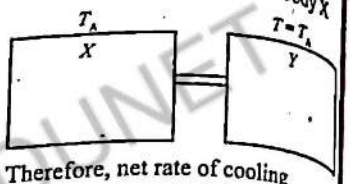
In the second part ($t > t_1$), body X cools by radiation (according to Newton's law) as well as by conduction.

In conduction,

$$\frac{dQ}{dt} = \frac{KA(T - T_A)}{L} = C\left(-\frac{dT}{dt}\right)$$

$$\therefore \left(-\frac{dT}{dt}\right) = \frac{KA}{LC}(T - T_A)$$

where, C = heat capacity of body X



Therefore, net rate of cooling

=(cooling by radiation)+(cooling by conduction)

$$\therefore \left(-\frac{dT}{dt}\right) = k(T - T_A) + \frac{KA}{CL}(T - T_A)$$

$$\left(-\frac{dT}{dt}\right) = \left(k + \frac{KA}{CL}\right)(T - T_A)$$

Let at $t = 3t_1$, temperature of X becomes T_2

Then from Eq. (iii)

$$\int_{T_1}^{T_2}\frac{dT}{T - T_A} = -\left(k + \frac{KA}{LC}\right)\int_{t_1}^{3t_1}dt$$

$$\ln\left(\frac{T_2 - T_A}{T_1 - T_A}\right) = -\left(k + \frac{KA}{LC}\right)(2t_1)$$

$$= -\left(2kt_1 + \frac{2KA}{LC}t_1\right)$$

or $\ln\left(\dfrac{T_2 - 300}{350 - 300}\right) = -2\ln(2) - \dfrac{2KA}{LC}t_1$

$kt_1 = \ln(2)$ from Eq. (i).

This equation gives

$$T_2 = \left(300 + 12.5e^{\frac{-2KAt_1}{CL}}\right)\text{K}$$

37. Number of gram moles of He,

$$n = \frac{m}{M} = \frac{2\times10^3}{4} = 500$$

(a) $V_A = 10\text{m}^3$, $p_A = 5\times10^4\text{ N/m}^2$.

$$\therefore T_A = \frac{p_AV_A}{nR} = \frac{(10)(5\times10^4)}{(500)(8.31)}\text{K}$$

@FAKE_CBSE_X @RAJ_EDUNET

or $T_A = 120.34\text{K}$

Similarly, $V_B = 10\text{m}^3, p_B = 10 \times 10^4\ \text{N/m}^2$

$$\therefore T_B = \frac{(10)(10\times10^4)}{(500)(8.31)}\text{K}$$

$$\therefore T_B = 240.68\ \text{K}$$

$V_C = 20\text{m}^3, p_C = 10 \times 10^4\ \text{N/m}^2$

$$\therefore T_C = \frac{(20)(10\times10^4)}{(500)(8.31)}\text{K}$$

$T_C = 481.36\text{K}$

and $V_D = 20\text{m}^3, p_D = 5 \times 10^4\ \text{N/m}^2$

$$\therefore V_D = \frac{(20)(5\times10^4)}{(500)(8.31)}\text{K}$$

$T_D = 240.68\ \text{K}$

(*b*) No, it is not possible to tell afterwards which sample went through the process *ABC* or *ADC*. But during the process if we note down the work done in both the processes, then the process which require more work goes through process *ABC*.

(*c*) In the process *ABC*

$$\Delta U = nC_V\Delta T = n\left(\frac{3}{2}R\right)(T_C - T_A)$$

$$= (500)\left(\frac{3}{2}\right)(8.31)(481.36 - 120.34)\text{J}$$

$\Delta U = 2.25 \times 10^6\text{J}$ and

W = Area under BC

$(20-10)(10)\times10^4\text{J} = 10^6\text{J}$

$$\therefore Q_{ABC} = \Delta U + W = (2.25 \times 10^6 + 10^6)\text{J}$$

$Q_{ABC} = 3.25 \times 10^6\text{J}$

In the process *ADC* ΔU will be same (because it depends on initial and final temperatures only)

W = Area under $AD = (20-10)(5 \times 10^4)\text{J}$

$= 0.5 \times 10^6$

$$\therefore Q_{ADC} = \Delta U + W$$

$$= (2.25 \times 10^6 + 0.5 \times 10^6)\text{J} = 2.75 \times 10^6$$

38. The corresponding $P - V$ diagram is as shown in figure

Given $T_A = 300$ k, $n = 1$, $\gamma = 1.4$, $\frac{V_A}{V_B} = 16$ and $\frac{V_C}{V_B} = 2$

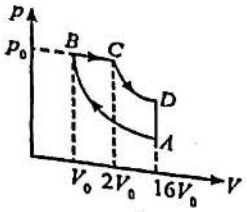
Let $V_B = V_0$ and $p_B = p_0$

Then, $V_C = 2V_0$ and $V_A = 16V_0$

Temperature at B

Process $A - B$ is adiabatic.

Hence, $T_A V_A^{\gamma-1} = T_B V_B^{\gamma-1}$



or $T_B = T_A\left(\frac{V_A}{V_B}\right)^{\gamma-1} = (300)(16)^{1.4-1}$

$T_B = 909\ \text{K}$

Temperature at *D*

$B \to C$ is an isobaric process

(p = constant)

$T \propto V$, $V_C = 2V_B$

$T_C = 2T_B = (2)(909)\text{K}$

$T_C = 1818\ \text{K}$

Now, the process $C \to D$ is adiabatic.

Therefore,

$$T_D = T_C\left(\frac{V_C}{V_D}\right)^{\gamma-1} = (1818)\left(\frac{2}{16}\right)^{1.4-1}$$

$T_D = 791.4\ \text{K}$

Efficiency of cycle

Efficiency of cycle (in percentage) is defined as

$$\eta = \frac{\text{Net work done in the cycle}}{\text{Heat absorbed in the cycle}} \times 100$$

or $\eta = \frac{W_{\text{Total}}}{Q_{+ve}} \times 100$

$$= \frac{Q_{+ve} - Q_{-ve}}{Q_{+ve}} \times 100 = \left(1 - \frac{Q_1}{Q_2}\right) \times 100 \quad \ldots(i)$$

where, Q_1 = negative heat in the cycle (heat released) and Q_2 = positive heat in the cycle (heat absorbed)

In the cycle

$Q_{AB} = Q_{CD} = 0$ (Adiabatic process)

$$Q_{DA} = nC_V\Delta T = (1)\left(\frac{5}{2}R\right)(T_A - T_D)$$

$C_V = \frac{5}{2}R$ for a diatomic gas

$$= \frac{5}{2} \times 8.31(300 - 791.4)\text{J}$$

or $Q_{DA} = -10208.8\text{J}$

$$Q_{BC} = nC_p\Delta T = (1)\left(\frac{7}{2}R\right)(T_C - T_B)$$

($C_P = \frac{7}{2}R$ for a diatomic gas)

$$\left(\frac{7}{2}\right)(8.31)(188 - 909)\text{J}$$

or $Q_{BC} = 26438.3\text{J}$

Therefore, substituting $Q_1 = 10208.8\text{J}$ and $Q_2 = 26438.3\text{J}$ in Eq. (*i*), we get

$$\therefore \eta = \left\{1 - \frac{10208.8}{26438.3}\right\} \times 100$$

or $n = 61.4\ \%$

39. (*a*) Number of moles of gas A are $n_A = 1$ (given) Let the number of moles of gas B be $n_B = n$ For a mixture

$$\frac{n_1 + n_2}{\gamma - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1} \quad \ldots(i)$$

Substituting the values in Eq. (*i*), we have

$$\frac{1+n}{\left(\frac{19}{13}\right)-1} = \frac{1}{\left(\frac{5}{3}\right)-1} + \frac{n}{\left(\frac{7}{5}\right)-1}$$

Solving this, we get $n = 2$.

(*b*) Molecular weight of the mixture will be given by,

$$M = \frac{n_A M_A + n_B M_B}{n_A + n_B}$$

$$= \frac{(1)(4) + 2(32)}{1+2}$$

$M = 22.67$

Speed of sound in a gas is given by

$$v = \sqrt{\frac{\gamma RT}{M}}$$

Therefore, in the mixture of the gas

(*c*) $$v = \sqrt{\frac{\left(\frac{19}{13}\right)(8.31)(300)}{22.67 \times 10^{-3}}}\ \text{m/s}$$

$v \approx 401$ m/s

(*i*) $v \propto \sqrt{T}$

$$v = KT^{\frac{1}{2}} \quad \ldots(ii)$$

or

$$\Rightarrow \frac{dv}{dT} = \frac{1}{2}KT^{-\frac{1}{2}} \Rightarrow dv = K\left(\frac{dT}{2\sqrt{T}}\right)$$

$$\Rightarrow \frac{dv}{v} = \frac{K}{v} \cdot \left(\frac{dT}{2\sqrt{T}}\right)$$

$$\Rightarrow \frac{dv}{v} = \frac{1}{\sqrt{T}}\left(\frac{dT}{2\sqrt{T}}\right) = \frac{1}{2}\left(\frac{dT}{T}\right)$$

$$\Rightarrow \frac{dv}{v} \times 100 = \frac{1}{2}\left(\frac{dT}{T}\right) \times 100$$

$$= \frac{1}{2}\left(\frac{1}{300}\right) \times 100 = 0.167$$

Therefore, percentage change in speed is 0.167%.

(*d*) Compressibility $= \frac{1}{\text{Bulk modulus}} = \beta$ (say)

@FAKE_CBSE_X @RAJ_EDUNET

Adiabatic bulk modulus is given by

$B_{adi} = \gamma p \left(B = -\frac{dp}{\frac{dV}{V}} \right)$

$\therefore$ Adiabatic compressibility will be given by

$\beta_{adi} = \frac{1}{\gamma p}$ and $\beta'_{adi} = \frac{1}{\gamma p'}$

$= \frac{1}{\gamma p(5)^{\gamma}} (pV^{\gamma} = \text{constant})$

$[pV\gamma = p'(V/5)\gamma \Rightarrow p' = p(5)\gamma$.

$\therefore \Delta\beta = \beta'_{adi} - \beta_{adi} = \frac{-1}{\gamma p}\left[1 - \left(\frac{1}{5}\right)^{\gamma}\right]$

$= \frac{-V}{\gamma(n_A + n_B)RT}\left[1 - \left(\frac{1}{5}\right)^{\gamma}\right]$

$\left(\because p = \frac{nRT}{V}\right)$

$= \frac{-V}{\left(\frac{19}{13}\right)(1+2)(8.31)(300)}\left[1 - \left(\frac{1}{5}\right)^{\frac{19}{13}}\right]$

$\left(\gamma = \gamma_{mixture} = \frac{19}{13}\right)$

$\Delta\beta = -8.27 \times 10^{-5} V$

40. (*a*) In a cyclic process $\Delta U_{net} = 0$

Therefore, $Q_{net} = W_{net}$

or $Q_1 + Q_2 + Q_3 + Q_4 = W_1 + W_2 + W_3 + W_4$

Hence, $W_4 = (Q_1 + Q_2 + Q_3 + Q_4) - (W_1 + W_2 + W_3)$

$= (5960 - 5585 - 2980 + 3645) - (2200 - 825 - 1100)$ or $W_4 = 765$ J

(*b*) Efficiency,

$\eta = \frac{\text{Total work done in the cycle}}{\text{Heat absorbed (positive heat)}} \times 100$

$= \left(\frac{W_1 + W_2 + W_3 + W_4}{Q_1 + Q_4}\right) \times 100$

$= \frac{1040}{9605} \times 100$

$\eta = 10.82\%$

NOTE

- From energy conservation

$W_{net} = Q_{+ve} - Q_{-ve}$ (in a cycle)

$\therefore \eta = \frac{W_{net}}{Q_{+ve}} \times 100 = \frac{(Q_{+ve} - Q_{-ve})}{Q_{+ve}} \times 100$

$= \left(1 - \frac{Q_{-ve}}{Q_{+ve}}\right) \times 100$

In the above question

$Q_{-ve} = |Q_2| + |Q_3| = (5585 + 2980)$J $= 8565$J

and $Q_{+ve} = Q_1 + Q_4 = (5960 + 3645)$J $= 9605$J

$\therefore \eta = \left(1 - \frac{8565}{9605}\right) \times 100$

$\eta = 10.82\%$

41. Given, $T_A = 1000$ K,

$p_B = \frac{2}{3} p_A, p_C = \frac{1}{3} p_A$

Number of moles, $n = 1, \gamma = \frac{C_p}{C_V} = \frac{5}{3}$ (mono-atomic)

(*a*) $A \to B$ is an adiabatic process, therefore

$p_A^{1-\gamma} T_A^{\gamma} = p_B^{1-\gamma} T_B^{\gamma}$

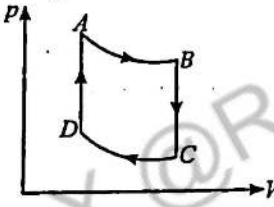
$\therefore T_B = T_A \left(\frac{p_A}{p_B}\right)^{\frac{1-\gamma}{\gamma}}$

$= (1000)\left(\frac{3}{2}\right)^{\frac{1-\frac{5}{3}}{\frac{5}{3}}} = (1000)\left(\frac{3}{2}\right)^{-\frac{2}{5}}$

$= (1000)\left(\frac{2}{3}\right)^{\frac{2}{5}}$

$T_B = (1000)(0.85)$

$\therefore T_B = 850$ K $= 850$K



Now, work done in the process $A \to B$ will be

$W_{AB} = \frac{R}{1-\gamma}(T_B - T_A)$

$= \frac{8.31}{1 - \frac{5}{3}}(850 - 1000)$ OR $W_{AB} = 1869.75$J

(*b*) $B \to C$ is an isochoric process

(V = constant)

$\therefore \frac{T_B}{T_C} = \frac{p_B}{p_C}$

$\therefore T_C = \left(\frac{p_C}{p_B}\right) T_B = \left(\frac{\left(\frac{1}{3}\right)p_A}{\left(\frac{2}{3}\right)p_A}\right) 850$ K

$T_C = 425$ K

Therefore,

$Q_{BC} = nC_V \Delta T = (1)\left(\frac{3}{2}R\right)(T_C - T_B)$

$= \left(\frac{3}{2}\right)(8.31)(425 - 850)$

$Q_{BC} = -5297.6$J

Therefore, heat lost in the process BC is 5297.6J.

(*c*) $C \to D$ and $A \to B$ are adiabatic processes. Therefore,

$p_C^{1-\gamma} T_C^{\gamma} = p_D^{1-\gamma} T_D^{\gamma} \Rightarrow \frac{p_C}{p_D} = \left(\frac{T_D}{T_C}\right)^{\frac{1}{1-\gamma}}$ ...(*i*)

$p_A^{1-\gamma} T_A^{\gamma} = p_B^{1-\gamma} T_B^{\gamma}$

$\Rightarrow \frac{p_A}{p_B} = \left(\frac{T_B}{T_A}\right)^{\frac{\gamma}{1-\gamma}}$ ...(*ii*)

Multiplying Eqs, (*i*) and (*ii*), we get

$\frac{p_C p_A}{p_D p_B} = \left(\frac{T_D T_B}{T_C T_A}\right)^{\frac{\gamma}{1-\gamma}}$ ...(*iii*)

Processes $B \to C$ and $D \to A$ are isochoric.

(V = constant)

Therefore, $\frac{p_C}{p_B} = \frac{T_C}{T_B}$ and $\frac{p_A}{p_D} = \frac{T_A}{T_D}$

Multiplying these two equations, we get

$\frac{p_C p_A}{p_D p_B} = \frac{T_C T_A}{T_B T_D}$ ...(*iv*)

From Eqn. (*iii*) and (*iv*), we have

$\left(\frac{T_D T_B}{T_C T_A}\right)^{\frac{\gamma}{1-\gamma}} = \left(\frac{T_C T_A}{T_B T_D}\right)$

or $\left(\frac{T_C T_A}{T_D T_B}\right)^{\frac{1-\gamma}{\gamma}} = \left(\frac{T_C T_A}{T_B T_D}\right)$

$\Rightarrow \frac{T_C T_A}{T_D T_B} = 1$

or $T_D = \frac{T_C T_A}{T_B} = \frac{(425)(1000)}{850}$

or $T_D = 500$ K

42. Given number of moles $n = 2$

Process AB and CD are isobaric.

Hence, $Q_{AB} = -Q_{CD}$

[Because $(\Delta T)_{AB} = 100$ K whereas $(\Delta T)_{CD} = -100$ K and $Q_{isobaric} = nc_p \Delta T$

or $Q_{AB} + Q_{AB} = 0$

Process BC is isothermal ($\Delta U = 0$)

$\therefore Q_{BC} = W_{BC} = nRT_B \ln\left(\frac{p_B}{p_C}\right)$

$= (2)(8.31)(400) \ln\left(\frac{2}{1}\right)$

$Q_{BC} = 4608$ J

Similarly, process DA is also isothermal hence,

@RAKE CBSE X @RAJ_EDUNET

$Q_{DA} = W_{DA} = nRT_D \ln\left(\frac{p_D}{p_A}\right)$

$= (2)(8.31)(300) \ln \frac{1}{2}$

$Q_{BC} = -3456$ J

(a) Net heat exchange in the process

$Q = Q_{AB} + Q_{BC} + Q_{CD} + Q_{DA}$.

$= (4608 - 3456)$J

$Q = 1152$J

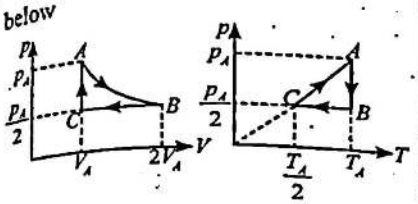
(b) From first law of thermodynamics, $\Delta U = 0$

(in complete cycle) $Q_{net} = W_{net}$

Hence, $W = Q = 1152$J

(c) Since, $T_i = T_f$ therefore net change in internal energy, $\Delta U = 0$

41. (a) The $p-V$ and $p-T$ diagrams are shown below



$(pV)_C = \frac{(pV)_A}{2} \Rightarrow \therefore T_C = \frac{T_A}{2}$

(b) Process $A-B$ T = constant

$\therefore p \propto \frac{1}{V}$, V is doubled. Therefore, p will become half.

Further, $V_A = \frac{nRT_A}{p_A} = \frac{3RT_A}{p_A}$

$\Delta U_{AB} = 0$

$\therefore Q_{AB} = W_{AB} = nRT_A \ln\left(\frac{2V_A}{V_A}\right)$

$= 3RT_A \ln(2) = 2.08\, RT_A$

Process $B-C$

$\therefore Q_{BC} = nC_p\Delta T = nCp\,(T_C - T_B)$

$= (3)\left(\frac{7}{2}R\right)\left(\frac{T_A}{2} - T_A\right) = -\frac{21}{4}RT_A$

$= -5.25\, RT_A$

Process $C-A$ V = constant

$W_{CA} = 0$

$\therefore Q_{CA} = \Delta U_{CA}\Delta T = nC_v\,(T_A - T_C)$

$= (3)\left(\frac{5}{2}R\right)\left(T_A - \frac{T_A}{2}\right) = 3.75\, RT_A$

In a cyclic process,

$\Delta U = 0$

$Q_{net} = W_{net} = (2.08 + 5.25 + 3.75)RT_A$

$= 0.58\, RT_A$

44. (a) In adiabatic process $TV^{\gamma-1}$ constant

$\therefore TV^{\gamma-1} = \left(\frac{T}{2}\right) 5.66V)^{\gamma-1}$

or $(5.66)^{\gamma-1} 2$

$\therefore (\gamma - 1) \ln (5.66) = \ln (2)$

$\therefore \gamma - 1 = 0.4$ or $\gamma = 1.4$

i.e. degree of freedom, $f = 5$ as $\gamma = 1 + \frac{2}{f}$.

(b) Using, PV^{γ} = constant

$pV^{1.4} = p_f(5.66V)^{1.4}$

$p_f = 0.09p$.

Now, work done in adiabatic process

$W = \frac{p_iV_i - p_fV_f}{\gamma - 1}$

$= \frac{(pV) - (0.09p)(5.66\,V)}{1.4 - 1} = 1.23pV$

45. No. of moles = 2

$r = \frac{5}{3}$

$T_2 = 300$ K $(27 + 275 = 300k)$

$V_i = 20$ *ltr*

$V_f = 40$ ltr

in constant pressure

$\rightarrow \frac{V_i}{T_i} = \frac{V_{f'}}{T_{f'}} \Rightarrow T_{f'} = 600k$

in adiabatic process

$TV^{\gamma-1} = k$

$T_{f'}V_{f'}^{\gamma-1} = T_i(V_f)^{\gamma-1}$

Solve & we get

$(600)(40)^{23} = (300)\,(2^{3/2})\,(40) = V_f$

Solve & we get

$W_{gas} = W_{IF} + W_{IF'}$

$= P\Delta V + nC_v\Delta T = 12459$ J

$V_f = 113.1$ ltr

for P_f use eqn of state

$nR = \frac{P_iV_i}{T_i} = \frac{P_fV_f}{T_f}\left(T_f = T_i\right)$

$P_i(20) = (113.1)P_f$

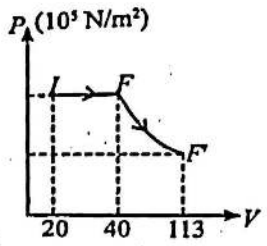
$2 \times (23) \times (300)$

$= P_f\left(\frac{(113.1)}{1000}\right)$ $11ltr = \frac{m^3}{1000}R$

$= 8.3$ Jk^{-1} mol^{-1}

$44{,}031.8302 = P_f$

$P_f = 0.44 \times 10^5$ N/m^2



46. For the right chamber

$P_0^{1-\gamma}T_0^{\gamma} = \left(\frac{243P}{32}\right)^{1-\gamma} T_2^{\gamma}$

$\Rightarrow T_2 = \frac{9}{4}T_0$ and $\frac{P_0V_0}{T_0} = \frac{\left(\frac{243P_0}{32}\right)V^2}{\left(\frac{9}{4}T_0\right)}$

$V_2 = \frac{9}{4} \times \frac{32}{243}V_0 = \frac{8}{27}V_0$

For the left chamber $\frac{P_0V_0}{T_0} = \frac{P_1V_1}{T_1}$ where

$P_1 = \frac{243}{32}P_0$

$V_1 = 2V_0 - \frac{8}{27}V_0 = \frac{46}{27}V_0$

$\Rightarrow T_1 = \frac{T_0}{P_0V_0} \times \left(\frac{243}{32}P_0\right)\left(\frac{46}{27}V_0\right)$

$= \frac{9 \times 23}{16}T_0 = 12.90\, T_0$

putting in T_2 we get.

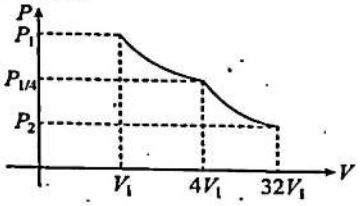
$T_2 = 2.25\, T_0$

Using 1st law, $w = -\Delta U = -1.875$ R

47. [2] $\frac{W_I}{W_{II}} = \frac{4P_0V_0 + 8P_0V_0\ell n2 - 6P_0V_0 - 0}{4P_0V_0\ell n2 - 0 - P_0V_0 + 0}$

$= \frac{8\ell n2 - 2}{4\ell n2 - 1} = 2$

48. [1.78]



$\frac{P_1}{4}(4V_1)^{5/3} = P_2(32V_1)^{5/3}$

$P_2 = \frac{P_1}{4}\left(\frac{1}{8}\right)^{5/3} = \frac{P_1}{128}$

$W_{adi} = \frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{P_1V_1 - \frac{P_1}{128}(32V_1)}{\frac{5}{3} - 1}$

@FAKE_CBSE_X @RAJ_EDUNET

$$= \frac{P_1V_1(3/4)}{2/3} = \frac{9}{8}P_1V_1$$

$$W_{iso} = P_1V_1 \ln\left(\frac{4V_1}{V_1}\right) = 2P_1V_1 \ln 2$$

$$\frac{W_{iso}}{W_{adia}} = \frac{2P_1V_1 \ln 2}{\frac{9}{8}P_1V_1} = \frac{16}{9}\ln 2 = f \ln 2$$

$$f = \frac{16}{9} = 1.7778 \approx 1.78$$

49. Under isothermal conditions, pV = constant

$(p_i)(2V) = pV \Rightarrow p_i = p/2$

Under adiabatic conditions,

pV^{γ} = Constant where $\gamma = 1.67$

$\therefore \quad (p_a)(2V)^{1.67} = pV^{1.67} \Rightarrow p_0 = p/(2)^{1.67}$

Therefore, the ratio $p_a/p_i = (2/2)^{1.67} = 0.628$

50. [True] We use the relation for the first law of thermodynamics, which states that:

$$\Delta q = \Delta U + w = \Delta U + \int p\,dV$$

and also $\Delta q = nC\Delta T$ for a constant volume process.

$$\Delta q = nC_v\Delta T = \Delta U + \int p(0)$$

i.e. $nC_v\Delta T = \Delta U$

for a constant pressure process

$$\Delta q = nC_v\Delta T = \Delta U + \int p(dV)$$

i.e. $nC_p\Delta T = \Delta U + \int p(dV)$

From the two relations we see that C_p is always greater than C_v because in a constant pressure process, work is done and part of the heat supplied goes into doing the work. Hence, the statement it true.

@FAKE_CBSE X @RAJ_EDUNET

15 Simple Harmonic Motion

Scan for ⦿ Sol.

JEE-Main

SHM: Equation, Phase Velocity, Acceleration, Time period

1. A particle executes simple harmonic motion with an amplitude of 4 cm. At the mean position, velocity of the particle is 10 cm/s. The distance of the particle from the mean position when its speed becomes 5 cm/s is $\sqrt{\alpha}$ cm, where $\alpha =$ _____.
[27 Jan, 2024 (Shift-I)]

2. A simple harmonic oscillator has an amplitude A and time period 6π second. Assuming the oscillation starts from its mean position, the time required by it to travel from $x = A$ to $x = \frac{\sqrt{3}}{2}A$ will be $\frac{\pi}{x}$ s, where x = _____:
[29 Jan, 2024 (Shift-II)]

3. A particle performs simple harmonic motion with amplitude A. Its speed is increased to three times at an instant when its displacement is $\frac{2A}{3}$. The new amplitude of motion is $\frac{nA}{3}$. The value of n is ____.
[31 Jan, 2024 (Shift-I)]

4. A mass m is suspended from a spring of negligible mass and the system oscillates with a frequency f_1. The frequency of oscillations if a mass 9 m is suspended from the same spring is f_2. The value of $\frac{f_1}{f_2}$ is _____.
[1 Feb, 2024 (Shift-II)]

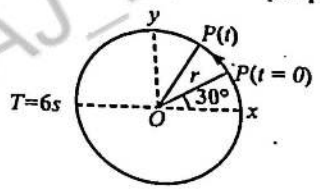
5. The displacement of a particle executing SHM is given by $x = 10\sin\left(\omega t + \frac{\pi}{3}\right)m$. The time period of motion is 3.14 s. The velocity of the particle at $t = 0$ is _____ m/s.
[04 April, 2024 (Shift-II)]

6. A particle is doing simple harmonic motion of amplitude 0.06 m and time period 3.14 s. The maximum velocity of the particle is _____ cm/s.
[06 April, 2024 (Shift-I)]

7. The position, velocity and acceleration of a particle executing simple harmonic motion are found to have magnitudes of 4 m, 2 ms^{-1} and 16 ms^{-2} at a certain instant. The amplitude of the motion is $\sqrt{x}$ m where x is _____.
[09 April, 2024 (Shift-I)]

8. A particle of mass 0.50 kg executes simple harmonic motion under force $F = -50(Nm^{-1})x$. The time period of oscillation is $\frac{x}{35}s$. The value of x is .....
(Given $\pi = 22?/7$)
[09 April, 2024 (Shift-II)]

9. For particle P revolving round the centre O with radius of circular path r and angular velocity ω, as shown in below figure, the projection of OP on the x-axis at time t is
[8 April, 2023 (Shift-II)]



(a) $x(t) = r\cos\left(\omega t + \frac{\pi}{6}\right)$ (b) $x(t) = r\cos(\omega t)$

(c) $x(t) = r\sin\left(\omega t + \frac{\pi}{6}\right)$ (d) $x(t) = r\cos\left(\omega t - \frac{\pi}{6}\omega\right)$

10. In a linear simple harmonic motion (SHM)
(A) Restoring force is directly proportional to the displacement.
(B) The acceleration and displacement are opposite in direction.
(C) The velocity is maximum at mean position.
(D) The acceleration is minimum at extreme points.
Choose the correct answer from the options given below :
[15 April, 2023 (Shift-I)]
(a) (A), (B) and (C) only (b) (C) and (D) only
(c) (A), (B) and (D) only (d) (A), (C) and (D) only

11. Assume that the earth is a solid sphere having uniform density and a tunnel is dug along its diameter throughout the earth. It is found that when a particle is released in this tunnel, it executes a simple harmonic motion. The mass of the particle is 100 g. The time period of the motion of the particle will be (approximately): ($g = 10m/s^2$, radius of earth = 6400 km) [25 Jan, 2023 (Shift-I)]
(a) 24 hours (b) 1 hour 24 minutes
(c) 1 hour 40 minutes (d) 12 hours

@FAKE_CBSE_@RAJ_EDUNET

12. A particle executes simple harmonic motion between $x=-A$ and $x=+A$. If time taken by the particle to go from $x=0$ to $\frac{A}{2}$ is $2s$; then time taken by the particle in going from $x=\frac{A}{2}$ to A will be: [25 Jan, 2023 (Shift-II)]

(a) $3s$ (b) $2s$
(c) $13..5s$ (d) $4s$

13. For a periodic motion represented by the equation $y=\sin\omega t+\cos\omega t$. The amplitude of the motion is [10 April, 2023 (Shift-II)]

(a) 14...5 (b) $\sqrt{2}$
(c) 1 (d) 2

14. A particle executes S.H.M. of amplitude A along x-axis. At $t=0$, the position of the particle is $x=\frac{A}{2}$ and it moves along positive x-axis the displacement of particle in time $t\,x=A\sin(\omega t+\delta)$, then the value of δ will be : [10 April, 2023 (Shift-I)]

(a) $\frac{\pi}{6}$ (b) $\frac{\pi}{3}$
(c) $\frac{\pi}{4}$ (d) $\frac{\pi}{2}$

15. Two simple harmonic waves having equal amplitudes of 8 *cm* and equal frequencies of 10 *Hz* are moving along the same direction. The resultant amplitude is also 8 *cm*. The phase difference between the individual waves is _____ degree. [29 Jan, 2023 (Shift-I)]

16. The velocity of a particle executing SHM varies with displacement (x) as $4v^2=50-x^2$. The time period of oscillations is $\frac{x}{7}s$. The value of x is ____ $\left(\text{Take}\,\pi=\frac{22}{7}\right)$ [30 Jan, 2023 (Shift-II)]

17. A particle of mass 250 g executes a simple harmonic motion under a periodic force $F=(-25x)$ N. The particle attains a maximum speed of $4m/s$ during its oscillation. The amplitude of the motion is _____ cm. [29 Jan, 2023 (Shift-II)]

18. When a particle executes Simple Hormonic Motion, the nature of graph of velocity as a function of displacement will be: [26 July, 2022 (Shift-I)]

(a) Circular (b) Elliptical
(c) Sinusoidal (d) Straight line

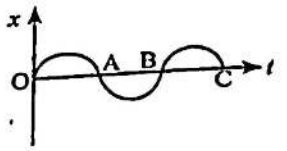
19. The displacement of simple harmonic oscillator after 3 seconds starting from its mean position is equal to half of its amplitude. The time period of harmonic motion is: [27 June, 2022 (Shift-I)]

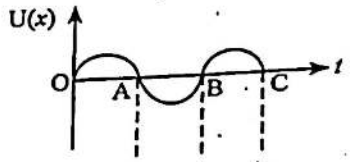
(a) 6 s. (b) 8 s
(c) 12 s (d) 36 s

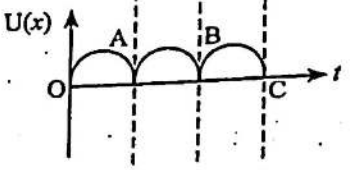
20. A particle executives simple harmonic motion. Its amplitude is 8 cm and time period is 6s. The time it will take to travel from its position of maximum displacement to the point corresponding to half of its amplitude, is _____s. [27 June, 2022 (Shift-II)]

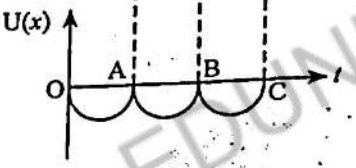
21. A body is performing simple harmonic with an amplitude of 10 cm. The velocity if the body was tripled by air Jet when it is at 5 cm from its mean position. The new amplitude vibration is $\sqrt{x}cm$. The value of x is _____. [29 June, 2022 (Shift-I)]

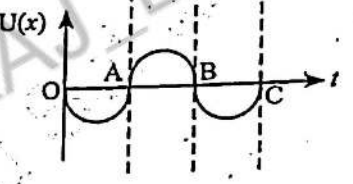
22. The variation of displacement with time of a particle executing simple harmonic motion is shown in the figure. The potential energy $U(x)$ versus time (t) plot of the particle is correctly shown in figure [27 Aug, 2021 (Shift-I)]



(a)


(b)


(c)


(d)


23. Assume that a tunnel is dug along a chord of the earth, at a perpendicular distance (R/2) from the earth's centre, where 'R' is the radius of the Earth. The wall of the tunnel is frictionless. If a particle is released in this tunnel, it will execute a simple harmonic motion with a time period: [26 Feb, 2021 (Shift-I)]

(a) $2\pi\sqrt{\frac{R}{g}}$ (b) $\frac{g}{2\pi R}$ (c) $\frac{1}{2p}\sqrt{\frac{g}{R}}$ (d) $\frac{2pR}{g}$

24. A particle executes S.H.M., the graph of velocity as a function of displacement is: [26 Feb, 2021 (Shift-II)]

(a) an ellipse (b) a circle
(c) a helix (d) a parabola

25. The function of time representing a simple harmonic motion with a period of $\frac{\pi}{\omega}$ is: [18 Mass(Shift-II)]

(a) $\cos(\omega t)+\cos(2\omega t)+\cos(3\omega t)$

(b) $\sin^2(\omega t)$

(c) $\sin(\omega t)+\cos(\omega t)$

(d) $3\cos\left(\frac{\pi}{4}-2\omega t\right)$

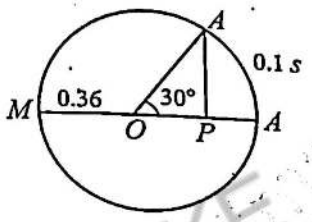
@FAKE_CODE_X@RAJ_EDUNET

26. When a particle executes SHM, the nature of graphical representation of velocity as a function of displacement is:
[24 Feb, 2021 (Shift-II)]
(a) Circular (b) Straight line
(c) Parabolic (d) Elliptical

27. A particle is making simple harmonic motion along the X-axis. If at a distances x_1 and x_2 from the mean position the velocities of the particle are v_1 and v_2 respectively. The time period of its oscillation is given as:
[20 July, 2021 (Shift-II)]
(a) $T=2\pi\sqrt{\frac{x_2^2-x_1^2}{v_1^2-v_2^2}}$ (b) $T=2\pi\sqrt{\frac{x_2^2+x_1^2}{v_1^2-v_2^2}}$
(c) $T=2\pi\sqrt{\frac{x_2^2-x_1^2}{v_1^2+v_2^2}}$ (d) $T=2\pi\sqrt{\frac{x_2^2+x_1^2}{v_1^2+v_2^2}}$

28. $Y=A\sin(\omega t+\phi_0)$ is the time-displacement equation of a SHM. At $t=0$ the displacement of the particle is $Y=\frac{A}{2}$ and it is moving along negative x-direction. Then the initial phase angle ϕ_0 will be:
[25 Feb, 2021 (Shift-II)]
(a) $\frac{5\pi}{6}$ (b) $\frac{\pi}{6}$
(c) $\frac{\pi}{3}$ (d) $\frac{2\pi}{3}$

29. The point A moves with a uniform speed along the circumference of a circle of radius 0.36 m and covers 30° in 0.1 s. The perpendicular projection 'P' from 'A' on the diameter MN represents the simple harmoic motion of 'P'. The restoration force per unit mass when P touches M will be:
[25 Feb, 2021 (Shift-II)]



(a) 100 N (b) 50 N
(c) 9.87 N (d) 0.49 N

30. Two simple harmonic motions are represented by the equations $x_1=5\sin\left(2\pi t+\frac{\pi}{4}\right)$ and $x_2=5\sqrt{2}(\sin 2\pi t+\cos 2\pi t)$. The amplitude of second motion is _____ times the amplitude in first motion.
[26 Aug, 2021 (Shift-II)]

31. A particle executes S.H.M. with amplitude 'a' and time period 'T'. The displacement of the particle when its speed is half of maximum speed is $\frac{\sqrt{x}a}{2}$. The value of x is ___.
[26 Feb, 2021 (Shift-II)]

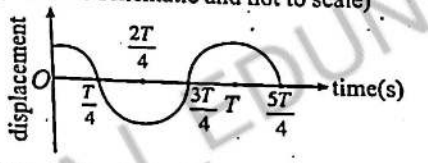
32. Two simple harmonic motion, are represented by the equations $y_1=10\sin\left(3\pi t+\frac{\pi}{3}\right)$ $y_2=5(\sin 3\pi t+\sqrt{3}\cos 3\pi t)$
Ratio of amplitude of y_1 to $y_2 = x : 1$. The value of x is ___
[27 Aug, 2021 (Shift-II)]

33. A particle performs simple harmonic motion with a period of 2 second. The time taken by the particle to cover a displacement equal to half of its amplitude from the mean positlon is $\frac{1}{a}s$.
The value of 'a' to the nearest integer is _____.
[18 March, 2021 (Shift-I)]

34. A particle executes simple harmonic motion represented by displacement function as $x(t)=A\sin(\omega t+\phi)$
If the position and velocity of the particle at $t=0$s are 2 cm and 2ω cm s^{-1} respectively, then its amplitude is $x\sqrt{2}$ cm where the value of x is _____:
[27 July, 2021 (Shift-II)]

35. A block of mass m attached to a massless spring is performing oscillatory motion of amplitude 'A' on a frictionless horizontal plane. If half of the mass of the block breaks off when it is passing through its equilibrium point, the amplitude of oscillation for the remaining system become fA. The value of f is
[3 Sep, 2020 (Shift-II)]
(a) $\frac{1}{\sqrt{2}}$ (b) $\sqrt{2}$ (c) 1 (d) $\frac{1}{2}$

36. The displacement time graph of a particle executing S.H.M is given in figure (sketch is schematic and not to scale)



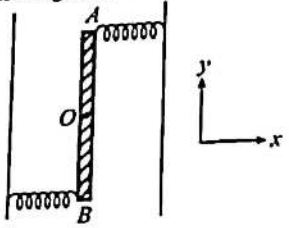
Which of the following statements is/are true for this motion?
[2 Sep, 2020 (Shift-II)]
A. The force is zero at $t=\frac{3T}{4}$
B. The acceleration is maximum at $t=T$
C. The speed is maximum at $t=\frac{T}{4}$
D. The P.E. is equal to K.E. of the oscillation at $t=\frac{T}{2}$
(a) B, C and D (b) A and D
(c) A, B and C (d) A, B and D

37. A ring is hung on a nail. It can oscillate, without slipping or sliding (*i*) in its plane with a time period T_1 and, (*ii*) back and forth in a direction perpendicular to its plane, with a period T_2. The ratio $\frac{T_1}{T_2}$ will be
[5 Sep, 2020 (Shift-II)]
(a) $\frac{\sqrt{2}}{3}$ (b) $\frac{2}{\sqrt{3}}$ (c) $\frac{2}{3}$ (d) $\frac{3}{\sqrt{2}}$

38. A small circular loop of conducting wire has radius a and carries current I. It is placed in a uniform magnetic field B perpendicular to its plane such that when rotated slightly about its diameter and released, it starts performing simple harmonic motion of time period T. If the mass of the loop is m then:
[9 Jan, 2020 (Shift-II)]
(a) $T=\sqrt{\frac{\pi m}{IB}}$ (b) $T=\sqrt{\frac{\pi m}{2IB}}$
(c) $T=\sqrt{\frac{2\pi m}{IB}}$ (d) $T=\sqrt{\frac{2m}{IB}}$

@FAKE_CBSE_X @RAJ_EDUNET

39. Two light identical springs of spring constant k are attached horizontally at the two ends of a uniform horizontal rod AB of length l and mass m. The rod is pivoted at its centre 'O' and can rotate freely in horizontal plane. The other ends of the two springs are fixed to rigid supports as shown in figure. The rod is gently pushed through a small angle and released. The frequency of resulting oscillation is: **[12 Jan, 2019 (Shift-I)]**



(a) $\frac{1}{2\pi}\sqrt{\frac{3k}{m}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{2k}{m}}$ (c) $\frac{1}{2\pi}\sqrt{\frac{6k}{m}}$ (d) $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$

40. A simple haromic motion is represented by:

$y = 5\left(\sin 3\pi t + \sqrt{3}\cos 3\pi t\right)$ cm

The amplitude and time period of the motion are:

[12 Jan, 2019 (Shift-II)]

(a) 10 cm, $\frac{2}{3}s$ (b) 10 cm, $\frac{3}{2}s$

(c) 5 cm, $\frac{3}{2}s$ (d) 5 cm, $\frac{2}{3}s$

41. A cylindrical plastic bottle of negligible mass of filled with 310 ml of water and left floating in a pond with still water. If pressed downward slightly and released, it starts performing simple harmonic motion at angular frequency ω. If the radius of the bottle is 2.5 cm then ω is close to: (density of water $= 10^3$ kg/m^3) **[10 Jan, 2019 (Shift-II)]**

(a) 41..75 rad s^{-1} (b) 1.25 rad s^{-1}

(c) 42..50 rad s^{-1} (d) 5.00 rad s^{-1}

Energy in SHM

42. When the displacement of a simple harmonic oscillator is one third of its amplitude, the ratio of total energy to the kinetic energy is $\frac{x}{8}$, where $x =$ _____.

[29 Jan, 2024 (Shift-I)]

43. An object of mass 0.2 kg executes simple harmonic motion along x axis with frequency of $\left(\frac{25}{\pi}\right)$Hz. At the position $x = 0.04$ m the object has kinetic energy 0.5 J and potential energy 0.4 J. The amplitude of oscillation is ..... cm. **[8 April 2024 (Shift-II)]**

44. A particle executes SHM of amplitude A. The distance from the mean position when its's kinetic energy becomes equal to its potential energy is : **[13 April 2023 (Shift-II)]**

(a) $\sqrt{2}$A (b) $2A$

(c) $\frac{1}{\sqrt{2}}$ A (d) $\frac{1}{2}$ A

45. The maximum potential energy of a block executing simple harmonic motion is 25 J. A is amplitude of oscillation. At A/2, the kinetic energy of the block is **[31 Jan, 2023 (Shift-I)]**

(a) 45.5 J (b) 9.75 J

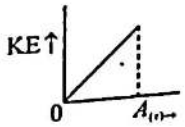
(c) 18.75 J (d) 12.5 J

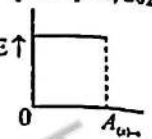
46. A particle is executing Simple Harmonic Motion (SHM). The ratio of potential energy and kinetic energy of the particle when its displacement is half of its amplitude will be: **[12 April, 2023 (Shift-II)]**

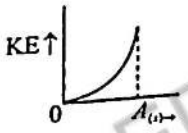
(a) 1 : 1 (b) 2 : 1

(c) 1 : 4 (d) 1 : 3

47. The variation of kinetic energy (KE) of a particle executing simple harmonic motion with the displacement (x) starting from mean position to extreme position (A) is given by (1) **[11 April, 2023 (Shift-I)]**

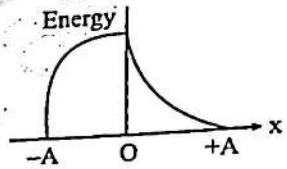
(a) 

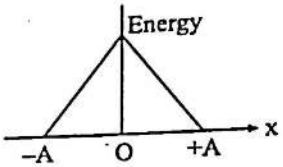
(b) 

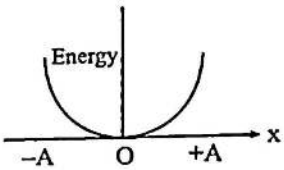
(c) 

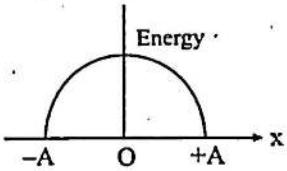
(d)

48. Which graph represents the difference between total energy and potential energy of a particle executing SHM Vs it's distance from mean position? **[13 April, 2023 (Shift-I)]**

(a) 

(b) 

(c) 

(d) 

49. The general displacement of a simple harmonic oscillator is $x = A\sin\omega t$. Let T be its time period. The slope of its potential energy (U) - time (t) curve will be maximum when $t = \frac{T}{\beta}$. The value of β is _____. **[30 Jan, 2023 (Shift-I)]**

@FAKE_CBSE_@RAJEDUNET

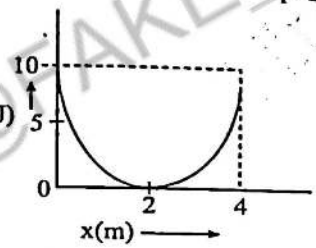
50. At a given point of time the value of displacement of a simple harmonic oscillator is given as $y = A\cos(30°)$. If amplitude is 40 cm and kinetic energy at that time is 200 J, the value of force constant is 1.0×10^{x} Nm^{-1}. The value of x is _____.
[13 April, 2023 (Shift-I)]

51. The amplitude of a particle executing SHM is 3 cm. The displacement at which its kinetic energy will be 25% more than the potential energy is _____ cm.
[1 Feb, 2023 (Shift-I)]

52. For a body executing S.H.M.:
(A) Potential energy is always equal to its K.E.
(B) Average potential and kinetic energy over any given time interval are always equal.
(C) Sum of the kinetic and potential energy at any point of time is constant.
(D) Average K.E. in one time period is equal to average potential energy in one time period.
Choose the most appropriate option from the options given below:
[31 Aug, 2021 (Shift-II)]
(a) Only (B) (b) (B) and (C)
(c) Only (C) (d) (C) and (D)

53. An object of mass 0.5 kg executing simple harmonic motion. Its amplitude is 5 cm and time period (T) is 0.2 s. What will be the potential energy of the object at an instant $t = \frac{T}{4}s$ starting from mean position. Assume that the initial phase of the oscillation is zero.
[27 July, 2021 (Shift-II)]
(a) 53....2×10^{-3} J (b) 0.62 J
(c) 54....2×10^{3} J (d) 1.2×10^{3} J

54. A mass of 5 kg is connected to a spring. The potential energy curve of the simple harmonic motion executed by the system is shown in the figure. A simple pendulum of length 4 m has the same period of oscillation as the spring system. What is the value of acceleration due to gravity on the planet where these experiments are performed?
[1 Sep, 2021 (Shift-II)]



(a) 54.....8 m/s^2 (b) 10 m/s^2 (c) 5 m/s^2 (d) 4 m/s^2

55. A particle starts executing simple harmonic motion (SHM) of amplitude 'a' and total energy E. At any instant, its kinetic energy is $3E/4$ then its displacement 'y' is given by:
[27 July, 2021 (Shift-I)]
(a) $y = \frac{a}{2}$ (b) $y = \frac{a}{\sqrt{2}}$
(c) $y = \frac{a\sqrt{3}}{2}$ (d) $y = a$

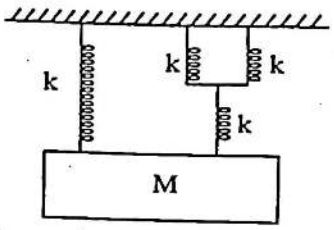
56. In a simple harmonic oscillation, what fraction of total mechanical energy is in the form of kinetic energy, when the particle is midway between mean and extreme position? [25 July, 2021 (Shift-II)]
(a) $\frac{1}{2}$ (b) $\frac{3}{4}$ (c) $\frac{1}{3}$ (d) $\frac{1}{4}$

57. A pendulum is executing simple harmonic motion and its maximum kinetic energy is K_1. If the length of the pendulum is doubled and it performs simple harmonic motion with the same amplitude as in the first case, its maximum kinetic energy is K_2 then:
[11 Jan, 2019 (Shift-II)]
(a) $K_2 = 2K_1$ (b) $K_2 = \frac{K_1}{2}$
(c) $K_2 = \frac{K_1}{4}$ (d) $K_2 = K_1$

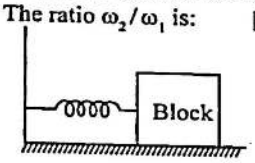
58. A particle undergoing simple harmonic motion has time dependent displacement given by $x(t) = A\sin\frac{\pi t}{90}$. The ratio of kinetic to potential energy of the particle at $t = 210$ s will be
[11 Jan, 2019 (Shift-I)]
(a) 1/9 (b) 1 (c) 2 (d) 3

Spring Mass Systems

59. The time period of simple harmonic motion of mass M in the given figure $\sqrt{\frac{\alpha M}{5K}}$ is, where the value of α is _____.
[31 Jan, 2024 (Shift-II)]

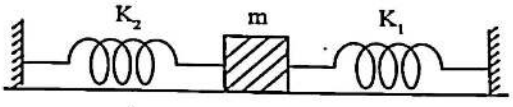


60. For a simple harmonic motion in a mass spring system shown, the surface is frictionless. When the mass of the block is 1kg, the angular frequency is ω_1. When the mass of the block is 2 kg the angular frequency is ω_2. The ratio ω_2/ω_1 is: [30 Jan, 2023 (Shift-II)]



(a) $\sqrt{2}$ (b) $\frac{1}{\sqrt{2}}$ (c) 2 (d) $\frac{1}{2}$

61. A mass m is attached to two springs as shown in figure. The spring constants of two springs are K_1 and K_2. For the frictionless surface, the time period of oscillation of mass m is
[06 April, 2023 (Shift-I)]

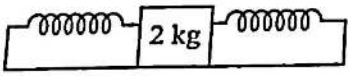


@TAKE_CARE_K @RAJ_EDUNET

(a) $\frac{1}{2\pi}\sqrt{\frac{K_1+K_2}{m}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{K_1-K_2}{m}}$

(c) $2\pi\sqrt{\frac{m}{K_1+K_2}}$ (d) $2\pi\sqrt{\frac{m}{K_1-K_2}}$

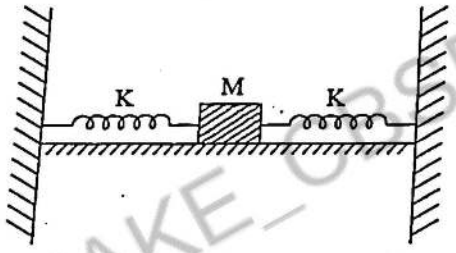
62. A block of mass 2 *kg* is attached with two identical springs of spring constant 20*N/m* each. The block is placed on a frictionless surface and the ends of the springs are attached to rigid supports (see figure). When the mass is displaced from its equilibrium position, it executes a simple harmonic motion. The time period of oscillation is $\frac{\pi}{\sqrt{x}}$ in SI unit. The value of x is **[24 Jan, 2023 (Shift-I)]**



63. A mass m attached to free end of a spring executes SHM with a period of 1*s*. If the mass is increased by 3 *kg* the period of oscillation increases by one second, the value of mass m is _____ *kg*. **[24 Jan, 2023 (Shift-II)]**

64. A rectangular block of mass 5 kg attached to a horizontal spiral spring executes simple harmonic motion of amplitude 1 *m* and time period 3.14 *s*. The maximum force exerted by spring on block is _____ *N*. **[10 April, 2023 (Shift-II)]**

65. In the figure given below. a block of mass $M = 490\ g$ placed on a frictionless table is connected with two springs having same spring constant ($K = 2N\,m^{-1}$). If the block is displaced horizontally through 'X' m then the number of complete oscillations it will make in 14π seconds will be _____. **[31 Jan, 2023 (Shift-I)]**



66. A block is fastened to a horizontal spring. The block is pulled to a distance $x = 10\ cm$ from its equilibrium position (at $x = 0$) on a frictionless surface from rest. The energy of the block at $x = 5\ cm$ is 0.25 *J*. The spring constant of the spring is _____ Nm^{-1}. **[1 Feb, 2023 (Shift-II)]**

67. Two massless springs with spring constants 2k and 9k, carry 50g and 100g masses at their free ends. These two masses oscillate vertically such that their maximum velocities are equal. Then, the ratio of their respective amplitudes will **[24 June, 2022 (Shift-II)]**

(a) 1 : 2 (b) 3 : 2

(c) 3 : 1 (d) 2 : 3

68. As per given figures, two spring constants k and 2k are connected to mass m. If the period of oscillation in figure (a) is 3s, then the period of oscillation in figure (b) will be $\sqrt{x}s$. The value of x is _____. **[26 July, 2022 (Shift-II)]**

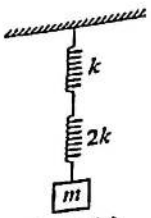


figure (a)

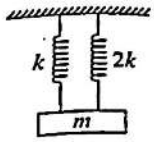
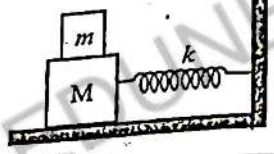


figure (b)

69. On a frictionless horizontal plane, a bob of mass $m = 0.1$ kg attached to a spring with natural length $l_0 = 0.1$ m. The spring constant is $k_1 = 0.009\ Nm^{-1}$ when the length of the spring $l > l_0$ is $k_2 = 0.016\ Nm^{-1}$ when $l < l_0$. Initially the bob is released from $l = 0.15$ m. Assume that Hooke's law remains valid throughout the motion. If the time period of the full oscillation is $T = (n\pi)$ s, then the integer closest to n is _____. **[JEE Adv, 2022]**

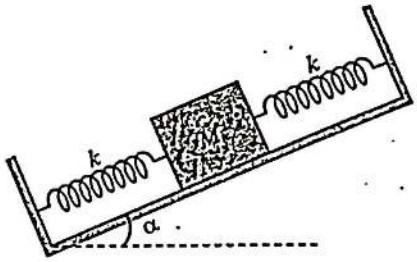
70. In the given figure, a mass M is attached to a horizontal spring which is fixed on one side to a rigid support. The spring constant of the spring is k. The mass oscillates on a frictionless surface with time period T and amplitude A. When the mass is in equilibrium position as shown in the figure, another mass m is gently fixed upon it. The amplitude of oscillation will be: **[24 Feb, 2021 (Shift-I)]**



(a) $A\sqrt{\frac{M}{M-m}}$ (b) $A\sqrt{\frac{M}{M+m}}$

(c) $A\sqrt{\frac{M-m}{M}}$ (d) $A\sqrt{\frac{M+m}{M}}$

71. In the given figure, a body of mass M is held between two massless springs, on a smooth inclined plane. The free ends of the springs are attached to firm supports. If each spring has spring constant k, the frequency of oscillation of given body is: **[24 Feb, 2021 (Shift-II)]**



(a) $\frac{1}{2\pi}\sqrt{\frac{k}{2m}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{k}{Mg\sin\alpha}}$

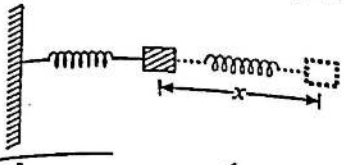
(c) $\frac{1}{2\pi}\sqrt{\frac{2k}{M}}$ (d) $\frac{1}{2\pi}\sqrt{\frac{2k}{Mg\sin\alpha}}$

72. If two similar spring each of spring constant K_1 are joined in series the new spring constant and time period would be changed by a factor : **[26 Feb, 2021 (Shift-I)]**

(a) $\frac{1}{2}, \sqrt{2}$ (b) $\frac{1}{2}, 2\sqrt{2}$ (c) $\frac{1}{4}, 2\sqrt{2}$ (d) $\frac{1}{4}, \sqrt{2}$

@FAKE_JEE X @RAJ_EDUNET

73. The motion of a mass on a spring, with spring constant K is as shown in figure. The equation of motion is given by $x(t) = A\sin\omega t + B\cos\omega t$ with $\omega = \sqrt{\frac{K}{m}}$. Suppose that at time $t = 0$, the position of mass is $x(0)$ and velocity $v(0)$, then its displacement can also be represented as $x(t) = C\cos(\omega t - \phi)$, where C and ϕ are: **[22 July, 2021 (Shift-II)]**



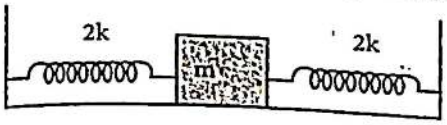
(a) $C = \sqrt{\frac{v(0)^2}{\omega^2} + x(0)^2}, \phi = \tan^{-1}\left(\frac{x(0)\omega}{v(0)}\right)$

(b) $C = \sqrt{\frac{2v(0)^2}{\omega^2} + x(0)^2}, \phi = \tan^{-1}\left(\frac{x(0)\omega}{2v(0)}\right)$

(c) $C = \sqrt{\frac{v(0)^2}{\omega^2} + x(0)^2}, \phi = \tan^{-1}\left(\frac{v(0)}{x(0)\omega}\right)$

(d) $C = \sqrt{\frac{2v(0)^2}{\omega^2} + x(0)^2}, \phi = \tan^{-1}\left(\frac{v(0)}{x(0)\omega}\right)$

74. Two identical springs of spring constant '2k' are attached to a block of mass m and to fixed support (see figure). When the mass is displaced from equilibrium position on either side, it executes simple harmonic motion. The time period of oscillations of this system is: **[25 Feb, 2021 (Shift-II)]**



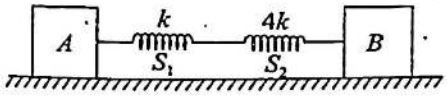
(a) $\pi\sqrt{\frac{m}{k}}$ (b) $\pi\sqrt{\frac{m}{2k}}$

(c) $2\pi\sqrt{\frac{m}{k}}$ (d) $2\pi\sqrt{\frac{m}{2k}}$

75. Two particles A and B of equal masses are suspended from two massless springs of spring constants K_1 and K_2 respectively. If the maximum velocities during oscillations are equal, the ratio of the amplitude of A and B is **[17 March, 2021 (Shift-II)]**

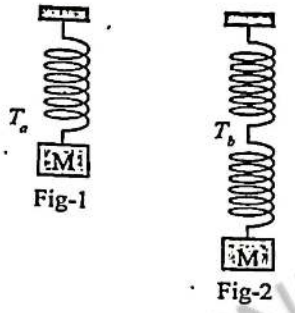
(a) $\frac{K_1}{K_2}$ (b) $\sqrt{\frac{K_1}{K_2}}$ (c) $\frac{K_2}{K_1}$ (d) $\sqrt{\frac{K_2}{K_1}}$

76. In the reported figure, two bodies A and B of masses 200g and 800g are attached with the system of springs. Springs are kept in a stretched position with some extension when the system is released. The horizontal surface is assumed to be frictionless. The angular frequency will be _____ rad/s when $k = 20$ N/m. **[25 July, 2021 (Shift-I)]**



77. Consider two identical springs each of spring constant k and negligible mass compared to the mass M as shown. Fig. 1 shows one of them and Fig. 2 shows their series combination. The ratios of time period of oscillation of the two SHM is $\frac{T_b}{T_a} = \sqrt{x}$, Where value of x is _____. **[17 March, 2021 (Shift-I)]**

(Round off to the Nearest Integer)

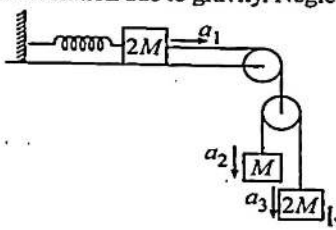


78. When a particle of mass m is attached to a vertical spring of spring constant k and released, its motion is described by $y(t) = y_0\sin^2\omega t$, where 'y' is measured from the lower end of unstretched spring. Then ω is **[6 Sep, 2020 (Shift-II)]**

(a) $\sqrt{\frac{5g}{y_0}}$ (b) $\frac{1}{2}\sqrt{\frac{g}{y_0}}$

(c) $\sqrt{\frac{g}{2y_0}}$ (d) $\sqrt{\frac{g}{y_0}}$

79. A block of mass $2M$ is attached to a massless spring with spring-constant k. This block is connected to two other blocks of masses M and $2M$ using two massless pulleys and strings. The accelerations of the blocks are a_1, a_2, and a_3 as shown in figure. The system is released from rest with the spring in its unstretched stale. The maximum extension of the spring is x_0. Which of the following option(s) is/are correct? [g is the acceleration due to gravity. Neglect friction]



[JEE Adv, 2019]

(a) $x_0 = \frac{4Mg}{k}$

(b) When spring achieves an extension of $x_0/2$ for the first time, the speed of the block connected to the spring is $3g\sqrt{\frac{M}{5k}}$

(c) $a_2 - a_1 = a_1 - a_3$

(d) At an extension of $x_0/4$ of the spring, the magnitude of acceleration of the block connected to the spring is $\frac{3g}{10}$

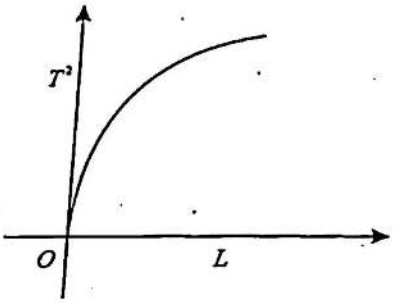
@FAKE_CBSE_X@RAJ_EDUNET

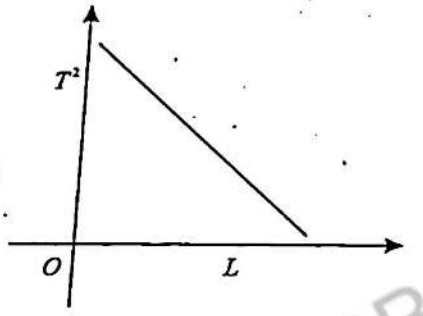
Pendulum

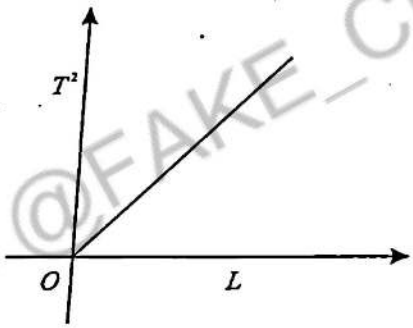
80. A simple pendulum doing small oscillations at a place R height above earth surface has time period of $T_1 = 4s$. T_2 would be it's time period if it is brought to a point which is at a height $2R$ from earth surface. Choose the correct relation [R = radius of Earth]:
[05 April, 2024 (Shift-I)]

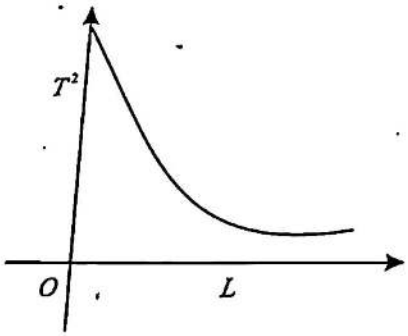
(a) $T_1 = T_2$ (b) $2T_1 = 3T_2$
(c) $3T_1 = 2T_2$ (d) $2T_1 = T_2$

81. Choose the correct length (L) versus square of time period (T^2) graph for a simple pendulum executing simple harmonic motion.
[1 Feb, 2023 (Shift-II)]

(a)


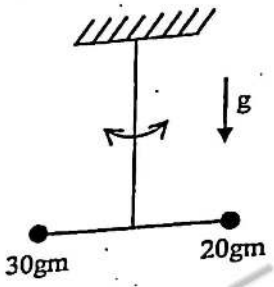
(b)


(c)


(d)


82. A simple pendulum with length 100 cm and bob of mass 250 g is executing S.H.M. of amplitude 10 cm. The maximum tension in the string is found to be $\frac{x}{40}N$. The value of x is
[6 April, 2023 (Shift-I)]

83. Two point-like objects of masses 20 gm and 30 gm are fixed at the two ends of a rigid massless rod of length 10 cm. This system is suspended vertically from a rigid ceiling using a thin wire attached to its center of mass, as shown in the figure. The resulting torsional pendulum undergoes small oscillations. The torsional constant of the wire is 1.2×10^{-8} N m rad^{-1}. The angular frequency of the oscillations is $n \times 10^{-3}$ rad s^{-1}. The value of n is _____.
[JEE Adv, 2023]



84. Time period of a simple pendulum in a stationary lift is 'T'. If the lift accelerates with $\frac{g}{6}$ vertically upwards then the time period will be:
[26 June, 2022 (Shift-I)]
(Where g = acceleration due to gravity)

(a) $\sqrt{\frac{6}{5}}$ T (b) $\sqrt{\frac{5}{6}}$ T (c) $\sqrt{\frac{6}{7}}$ T (d) $\sqrt{\frac{7}{6}}$ T

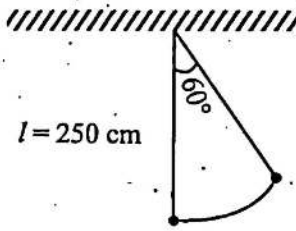
85. The time period of oscillation of a simple pendulum of length L suspended from the roof of a vehicle, which moves without friction down an inclined plane of inclination α, is given by.[29 July, 2022 (Shift-I)]

(a) $2\pi\sqrt{L/(g\cos\alpha)}$ (b) $2\pi\sqrt{L/(g\sin\alpha)}$
(c) $2\pi\sqrt{L/g}$ (d) $2\pi\sqrt{L/(g\tan\alpha)}$

86. The motion of a simple pendulum executing S.H.M. is represented by the following equation. $y = A\sin(\pi t + \phi)$, where time is measured in second. The length of pendulum is: [29 June, 2022 (Shift-II)]

(a) 86..23 cm (b) 25.3 cm
(c) 87..4 cm (d) 406.1 cm

87. A pendulum is suspended by a string of length 250 cm. The mass of the bob of the pendulum is 200g. The bob is pulled aside until the string is at 60° with vertical as shown in the figure. After releasing the bob, the maximum velocity attained by the bob will be _____ ms^{-1}. (if $g = 10$ m/s^2)
[28 June, 2022 (Shift-I)]



88. The metallic bob of simple pendulum has the relative density 5. The time period of this pendulum is 10s. If the metallic bob is immersed in water, then the new time period becomes $5\sqrt{x}\,s$. The value of x will be _____.
[29 July, 2022 (Shift-II)]

@FAKE_CBSE X @RAJ_EDUNET

89. Time period of a simple pendulum is T inside a lift when the lift is stationary. If the lift moves upwards with an acceleration $g/2$, the time period of pendulum will be: **[16 March, 2021 (Shift-I)]**

(a) $\sqrt{\frac{2}{3}}T$ (b) $\sqrt{3}T$ (c) $\frac{T}{\sqrt{3}}$ (d) $\sqrt{\frac{3}{2}}T$

90. T_0 is the time period of a simple pendulum at a place. If the length of the pendulum is reduced to $\frac{1}{16}$ times of its initial value, the modified time period is:

[22 July, 2021 (Shift-II)]

(a) T_0 (b) $8\pi T_0$ (c) $4T_0$ (d) $\frac{1}{4}T_0$

91. If the time period of a two meter long simple pendulum is 2s, the acceleration due to gravity at the place where pendulum is executing S.H.M. is: **[25 Feb, 2021 (Shift-I)]**

(a) 91...8 ms^{-2} (b) 16 m/s^2
(c) $2\pi^2$ ms^{-2} (d) π^2 ms^{-2}

92. A bob of mass 'm' suspended by a thread of length l undergoes simple harmonic oscillations with time period T. If the bob is immersed in a liquid that has density 1/4 times that of the bob and the length of the thread is increased by 1/3rd of the original length, then the time period of the simple harmonic oscillations will be:

[31 Aug, 2021 (Shift-II)]

(a) $\frac{3}{4}T$ (b) $\frac{3}{2}T$ (c) T (d) $\frac{4}{3}T$

93. Given below are two statements: **[26 Feb, 2021 (Shift-II)]**

Statement-I: A second's pendulum has a time period of 1 second.

Statement-II: It takes precisely one second to move between the two extreme positions.

In the light of the above statements, choose the correct answer from the options given below:

(a) Both Statement-I and Statement-II are false
(b) Statement-I is false but Statement-II is true
(c) Statement-I is true but Statement-II is false
(d) Both Statement-I and Statement-II are true

94. Time period of a simple pendulum is T. The time taken to complete $\frac{5}{8}$ oscillations starting from mean position is $\frac{\alpha}{\beta}T$. The value of α is _____. **[26 Feb, 2021 (Shift-II)]**

95. A pendulum bob has a speed of 3 m/s at its lowest position. The pendulum is 50 cm long. The speed of bob, when the length makes an angle of 60° to the vertical will be ($g = 10 m/s^2$) _____ m/s. **[25 July, 2021 (Shift-I)]**

96. A simple pendulum of length 1 m is oscillating with an angular frequency 10 rad/s. The support of the pendulum starts oscillating up and down with a small angular frequency of 1 rad/s and an amplitude of 10^{-2} m. The relative change in the angular frequency of the pendulum is best given by **[11 Jan, 2019 (Shift-II)]**

(a) 10^{-3} rad/s (b) 1 rad/s
(c) 10^{-1} rad/s (d) 10^{-5} rad/s

97. A simple pendulum, made of a string of length l and a bob of mass m, is released from a small angle θ_0. It strikes a block of mass M, kept on a horizontal surface at its lowest point of oscillations, elastically. It bounces back and goes up to an angle θ_1. Then M is given by: **[12 Jan, 2019 (Shift-I)]**

(a) $\frac{m}{2}\left(\frac{\theta_0+\theta_1}{\theta_0-\theta_1}\right)$ (b) $m\left(\frac{\theta_0-\theta_1}{\theta_0+\theta_1}\right)$
(c) $m\left(\frac{\theta_0+\theta_1}{\theta_0-\theta_1}\right)$ (d) $\frac{m}{2}\left(\frac{\theta_0-\theta_1}{\theta_0+\theta_1}\right)$

98. A simple pendulum oscillating in air has period T. The bob of the pendulum is completely immersed in a non-viscous liquid. The density of the liquid is $\frac{1}{16}$th of the material of the bob. If the bob is inside liquid all the time, its period of oscillation in this liquid is: **[9 April, 2019 (Shift-I)]**

(a) $4T\sqrt{\frac{1}{15}}$ (b) $2T\sqrt{\frac{1}{10}}$ (c) $4T\sqrt{\frac{1}{14}}$ (d) $2T\sqrt{\frac{1}{14}}$

99. The mass and the diameter of a planet are three times the respective values for the Earth. The period of oscillation of a simple pendulum on the Earth is 2s. The period of oscillation of the same pendulum on the planet would be: **[11 Jan, 2019 (Shift-II)]**

(a) $\frac{\sqrt{3}}{2}s$ (b) $\frac{2}{\sqrt{3}}s$ (c) $\frac{3}{2}s$ (d) $2\sqrt{3}s$

JEE-Advanced

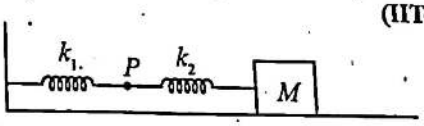
Displacement, Velocity and Acceleration in Shm

Single Correct

1. A point mass is subjected to two simultaneous sinusoidal displacements in x-direction, $x_1(t) = A \sin \omega t$ and $x_2(t) = A \sin(\omega t + 2\pi/3)$. Adding a third sinusoidal displacement $x_3(t) = B \sin(\omega t + \phi)$ brings the mass to a complete rest. The values of B and ϕ are **(IIT-JEE 2011)**

(a) $\sqrt{2}A, \frac{3\pi}{4}$ (b) $A, \frac{4\pi}{3}$ (c) $\sqrt{3}A, \frac{5\pi}{6}$ (d) $A, \frac{\pi}{3}$

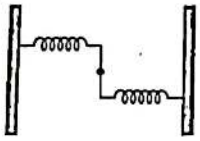
2. The mass M shown in the figure oscillates in simple harmonic motion with amplitude A. The amplitude of the point P is **(IIT-JEE 2009)**



(a) $(k_1A)/k_2$
(b) $(k_2A)/k_1$
(c) $(k_1A)/(k_1+k_2)$
(d) $(k_2A)/(k_1+k_2)$

@TAKE_OBSEX @RAJEEBNET

3. A uniform rod of length L and mass M is pivoted at the center. Its two ends are attached to two springs of equal spring constants k. The springs are fixed to rigid supports as shown in the figure and the rod is free to oscillate in the horizontal plane. The rod is gently pushed through a small angle θ in one direction and released. The frequency of oscillation is **(IIT-JEE 2009)**



(a) $\frac{1}{2\pi}\sqrt{\frac{2k}{M}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{k}{M}}$

(c) $\frac{1}{2\pi}\sqrt{\frac{6k}{M}}$ (d) $\frac{1}{2\pi}\sqrt{\frac{24k}{M}}$

4. A particle executes simple harmonic motion between $x = -A$ and $x = +A$. The time taken for it to go from O to $A/2$ is t_1 and to go from $A/2$ to A is t_2, then **(IIT JEE 2001)**

(a) $t_1 < t_2$ (b) $t_1 > t_2$ (c) $t_1 = t_2$ (d) $t_1 = 2t_2$

5. A uniform cylinder of length L and mass M having cross-sectional area A is suspended, with its length vertical, from a fixed point by a massless spring, such that it is half-submerged in a liquid of density ρ at equilibrium position. When the cylinder is given a small downward push and released it starts oscillating vertically with a small amplitude. If the force constant of the spring is k, the frequency of oscillation of the cylinder is **(IIT JEE 1990)**

(a) $\frac{1}{2\pi}\left(\frac{k-A\rho g}{M}\right)^{\frac{1}{2}}$ (b) $\frac{1}{2\pi}\left(\frac{k+A\rho g}{M}\right)^{\frac{1}{2}}$

(c) $\frac{1}{2\pi}\left(\frac{k-A\rho L^2}{M}\right)^{\frac{1}{2}}$ (d) $\frac{1}{2\pi}\left(\frac{k-A\rho g}{A\rho g}\right)^{\frac{1}{2}}$

6. Two bodies M and N of equal masses are suspended from two separate massless springs of spring constants k_1 and k_2 respectively. If the two bodies oscillate vertically such that their maximum velocities are equal, the ratio of the amplitude of vibration of M to that of N is **(IIT-JEE 1988)**

(a) $\frac{k_1}{k_2}$ (b) $\sqrt{\frac{k_2}{k_1}}$ (c) $\frac{k_2}{k_1}$ (d) $\sqrt{\frac{k_1}{k_2}}$

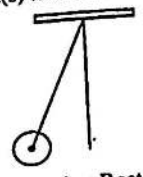
7. An ideal gas is enclosed in a vertical cylindrical container and supports a freely moving piston of mass M. The piston and the cylinder have equal cross-sectional area A. Atmospheric pressure is p_0 and when the piston is in equilibrium, the volume of the gas is V_0. The piston is now displaced slightly from its equilibrium position. Assuming that the system is completely isolated from its surroundings, show that the piston executes simple harmonic motion and find the frequency of oscillation. **(IIT-JEE 1981)**

(a) $\frac{A}{5\pi}\sqrt{\frac{\left(p_0+\frac{Mg}{A}\right)\gamma}{MV_0}}$ (b) $\frac{A}{2\pi}\sqrt{\frac{\left(p_0+\frac{Mg}{A}\right)\gamma}{MV_0}}$

(c) $\frac{A}{4\pi}\sqrt{\frac{\left(p_0+\frac{Mg}{A}\right)\gamma}{MV_0}}$ (d) $\frac{A}{6\pi}\sqrt{\frac{\left(p_0+\frac{Mg}{A}\right)\gamma}{MV_0}}$

Multiple Correct

8. A metal rod of length L and mass m is pivoted at one end. A thin disc of mass M and radius $R < L$ is attached at its center to the free end of the rod. Consider two ways the disc is attached. Case-A—the disc is not free to rotate about its center and Case-B—the disc is free to rotate about its center. The rod-disc system performs SHM in the vertical plane after being released from the same displaced position. Which of the following statement(s) is/are true? **(IIT-JEE 2011)**

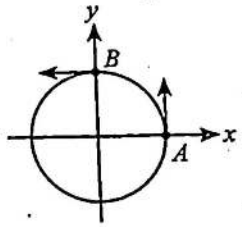
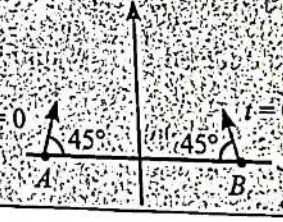


(a) Restoring torque in Case-A = Restoring torque in Case-B
(b) Restoring torque in Case-A < Restoring torque in Case-B
(c) Angular frequency for Case-A > Angular frequency for Case-B
(d) Angular frequency for Case-A < Angular frequency for Case-B

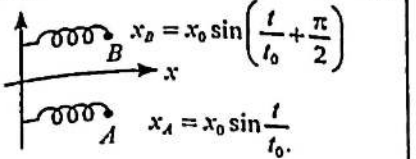
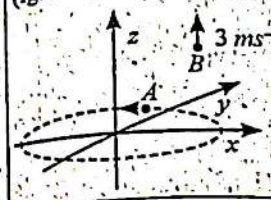
9. Function $x = A\sin^2\omega t + B\cos^2\omega t + C\sin\omega t\cos\omega t$ represents SHM **(IIT-JEE 2006)**

(a) For any value of A, B and C (except $C = 0$)
(b) If $A = -B$, $C = 2B$, amplitude $= |B\sqrt{2}|$
(c) If $A = B$; $C = 0$
(d) If $A = B$; $C = 2B$, amplitude $= |B|$

10. List-I describes four systems, each with two particles A and B in relative motion as shown in figures. List-II gives possible magnitudes of their relative velocities (in ms^{-1}) at time $t = \frac{\pi}{3}$ s.

List-I		List-II	
(I)	A and B are moving on a horizontal circle of radius 1 m with uniform angular speed $\omega = 1$ rad s^{-1} The initial angular positions of A and B at time $t = 0$ are $\theta = 0$ and $\theta = \frac{\pi}{2}$, respectively. 	P	$\frac{\sqrt{3}+1}{3}$
(II)	Projectiles A and B are fired (in the same vertical plane) at $t = 0$ and $t = 0.1$ s respectively, with the same speed $= v = \frac{5\pi}{\sqrt{2}}$ ms^{-1} and at 45° from the horizontal plane. The initial separation between A and B is large enough so that they do not collide. ($g = 10$ ms^{-2}). 	Q	$\sqrt{2}$

© FAKE - CODE X @ RULEDUNIET

(III)	Two harmonic oscillators A and B moving in the x direction according to $x_A = x_0 \sin \frac{t}{t_0}$ and $x_B = x_0 \sin\left(\frac{t}{t_0} + \frac{\pi}{2}\right)$ respectively, starting from $t = 0$. Take $x_0 = 1\ m$, $t_0 = 1\ s$. 	R	$\sqrt{10}$
(IV)	Particle A is rotating in a horizontal xy plane, with constant angular speed $\omega = 1$ rad s^{-1} in a circle of radius 1 m. Particle B is moving up at a constant speed 3 ms^{-1} in the vertical direction as shown in the figure. (Ignore gravity.) 	S	$\sqrt{2}$
		T	$\sqrt{25\pi^2 + 1}$

C34.29 W-18.91 UA-46.80 (JEE Adv. 2022)

Which one of the following options is correct?

(a) I → R, II → T, III → P, IV → S

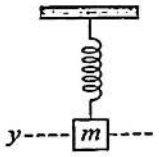
(b) I → S, II → P, III → Q, IV → R

(c) I → S, II → T, III → P, IV → R

(d) I → T, II → P, III → R, IV → S

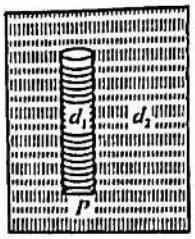
Subjective

11. A mass m is undergoing SHM in the vertical direction about the mean position y_0 with amplitude A and angular frequency ω. At a distance y from the mean position, the mass detaches from the spring. Assume that the spring contracts and does not obstruct the motion of m. Find the distance y (measured from the mean position) such that the height h attained by the block is maximum ($A\omega^2 > g$). **(IIT-JEE 2005)**



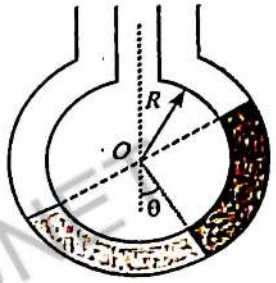
12. A solid sphere of radius R is floating in a liquid of density ρ with half of its volume submerged. If the sphere is slightly pushed and released, it starts performing simple harmonic motion. Find the frequency of these oscillations. **(IIT-JEE 2004)**

13. A thin rod of length L and uniform cross-section is pivoted at its lowest point P inside a stationary homogeneous and non-viscous liquid. The rod is free to rotate in a vertical plane about a horizontal axis passing through P.



The density d_1 of the material of the rod is smaller than the density d_2 of the liquid. The rod is displaced by small angle θ from its equilibrium position and then released. Show that the motion of the rod is simple harmonic and determine its angular frequency in terms of the given parameters. **(IIT-JEE 1996)**

14. Two non-viscous, incompressible and immiscible liquids of densities ρ and 1.5ρ are poured into the two limbs of a circular tube of radius R and small cross-section kept fixed in a vertical plane as shown in figure. Each liquid occupies one-fourth the circumference of the tube.



(a) Find the angle θ that the radius to the interface makes with the vertical in equilibrium position.

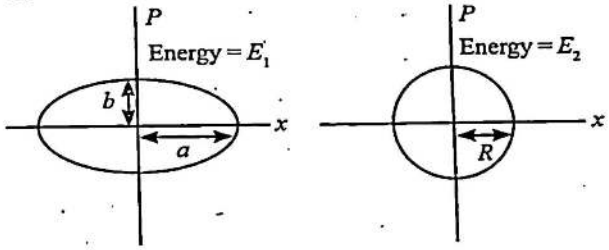
(b) If the whole liquid column is given a small displacement from its equilibrium position, show that the resulting oscillations are simple harmonic. Find the time period of these oscillations **(IIT-JEE 1991)**

15. Two simple harmonic motions are represented by the equations $y_1 = 10 \sin\left(3\pi t + \frac{\pi}{4}\right)$ and $y_2 = 5(\sin 3\pi t + \sqrt{3} \cos 3\pi t)$. Their amplitudes are in the ratio of ... **(IIT-JEE 1986)**

Energy in SHM

Single Correct

16. Two independent harmonic oscillators of equal masses are oscillating about the origin with angular frequencies ω_1 and ω_2 and have total energies E_1 and E_2, respectively. The variations of their momenta p with positions x are shown in the figures. If $\frac{a}{b} = n^2$ and $\frac{a}{R} = n$, then the correct equations is/are **(JEE Adv. 2015)**

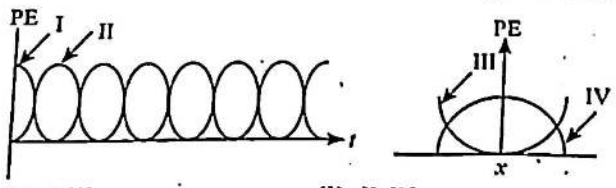


(a) $E_1\omega_1 = E_2\omega_2$ (b) $\omega_2/\omega_1 = n^2$

(c) $\omega_1\omega_2 = n^2$ (d) $E_1/\omega_1 = E_2/\omega_2$

@FREE CBSE X @RANK BOOSTER

17. For a particle executing SHM the displacement x is given by $x = A\cos\omega t$. Identify the graph which represents the variation of potential energy (P.E.) as a function of time t and displacement x. **(IIT-JEE 2003)**



(a) I, III (b) II, IV
(c) II, III (d) I, IV

18. A particle free to move along the X-axis has potential energy given by $U(x) = k[1 - \exp(-x^2)]$ for $-\infty \le x \le +\infty$, where k is a positive constant of appropriate dimensions. Then, **(IIT-JEE 1999)**

(a) At points away from the origin, the particle is in unstable equilibrium

(b) For any finite non-zero value of x, there is a force directed away from the origin

(c) if its total mechanical energy is $k/2$, it has its minimum kinetic energy at the origin

(d) for small displacements from $x = 0$, the motion is simple harmonic

19. A particle of mass m is executing oscillation about the origin on the X-axis. Its potential energy is $U(x) = k|x|^3$, where k is a positive constant. If the amplitude of oscillation is a, then its time period T is **(IIT-JEE 1998)**

(a) proportional to $1/\sqrt{a}$ (b) independent of a
(c) proportional to $\sqrt{a}$ (d) proportional to $a^{3/2}$

20. An object of mass 0.2 kg executes simple harmonic oscillations along the X-axis with a frequency of $\frac{25}{\pi}$ Hz. At the position $x = 0.04$, the object has kinetic energy of 0.5 J and potential energy 0.4 J. The amplitude of oscillations is ... **(IIT-JEE 1994)**

(a) 0.12 m (b) 0.06 m (c) 0.24 m (d) 1.2 m

21. A particle executes simple harmonic motion with a frequency f. The frequency with which its kinetic energy oscillates is **(IIT-JEE 1987)**

(a) $f/2$ (b) f (c) $2f$ (d) $4f$

Multiple Correct

22. Three simple harmonic motions in the same direction having the same amplitude a and same period are superposed. If each differ in phase from the next by 45°, then **(IIT-JEE 1999)**

(a) The resultant amplitude is $(1 + \sqrt{2})a$

(b) The phase of the resultant motion relative to the first is 90°

(c) The energy associated with the resulting motion is $(3 + 2\sqrt{2})$ times the energy associated with any single motion

(d) The resulting motion is not simple harmonic

23. A linear harmonic oscillator of force constant 2×10^6 N/m and amplitude 0.01 m has a total mechanical energy of 160 J. Its **(IIT-JEE 1989)**

(a) Maximum potential energy is 100 J

(b) Maximum kinetic energy is 100 J

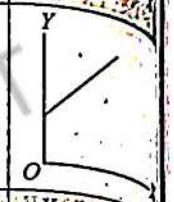
(c) Maximum potential energy is 160 J

(d) Maximum potential energy is zero

Match the Column

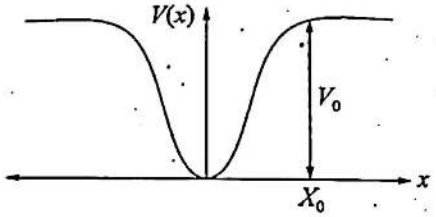
24. Column-I gives a list of possible sets of parameters measured in some experiments. The variations of the parameters in the form of graphs are shown in Column-II. Match the set of parameters given in Column-I with the graphs given in Column-II. **(IIT-JEE 2008)**

Consider the following lists:

	Column-I		Column-II
A.	Potential energy of a simple pendulum (Y-axis) as a function of displacement (X-axis).	p.	
B.	Displacement (Y-axis) as a function of time (X-axis) for a one dimensional motion at zero or constant acceleration when the body is moving along the positive x-direction.	q.	
C.	Range of a projectile (Y-axis) as a function of its velocity (X-axis) when projected at a fixed angle.	r.	
D.	The square of the time period (Y-axis) of a simple pendulum as a function of its length (X-axis).	s.	

Comprehension Based/Statement Based

Passage (Q.25 to Q.27): When a particle of mass m moves on the X-axis in a potential of the form $V(x) = kx^2$, it performs simple harmonic motion. The corresponding time period is proportional to $\sqrt{(m/k)}$, as can be seen easily using dimensional analysis. However, the motion of a particle can be periodic even when its potential energy increases on both sides of $x = 0$ in a way different from kx^2 and its total energy is such that the particle does not escape to infinity. Consider a particle of mass m moving on the X-axis. Its potential energy is $V(x) = \alpha x^4$ ($\alpha > 0$) for $|x|$ near the origin and becomes a constant equal to V_0 for $|x| \ge X_0$ (see figure).



25. If the total energy of the particle is E, it will perform periodic motion only if **(IIT-JEE 2010)**

(a) $E < 0$ (b) $E > 0$ (c) $V_0 > E > 0$ (d) $E > V_0$

26. The acceleration of this particle for $|x| > X_0$ is **(IIT-JEE 2010)**

(a) Proportional to V_0 (b) Proportional to $\frac{V_0}{mX_0}$

(c) Proportional to $\sqrt{\frac{V_0}{mX_0}}$ (d) Zero

@FAKE-CBSE-K@RAJDUNET

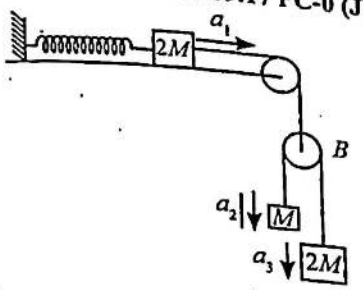
17. For periodic motion of small amplitude A, the time period T of this particle is proportional to **(IIT-JEE 2010)**

(a) $A\sqrt{\frac{m}{\alpha}}$ (b) $\frac{1}{A}\sqrt{\frac{m}{\alpha}}$ (c) $A\sqrt{\frac{\alpha}{m}}$ (d) $\frac{1}{A}\sqrt{\frac{\alpha}{m}}$

Spring Mass Systems

Single Correct

18. A block of mass $2M$ is attached to a massless spring with spring-constant k. This block is connected to two other blocks of masses M and $2M$ using two massless pulleys and strings. The accelerations of the blocks are a_1, a_2, and a_3 as shown in figure. The system is released from rest with the spring in its unstretched state. The maximum extension of the spring is x_0. Which of the following option(s) is/are correct? [g is the acceleration due to gravity. Neglect friction] **C-21.73 W-39.1 UA-39.17 PC-0 (JEE Adv. 2019)**



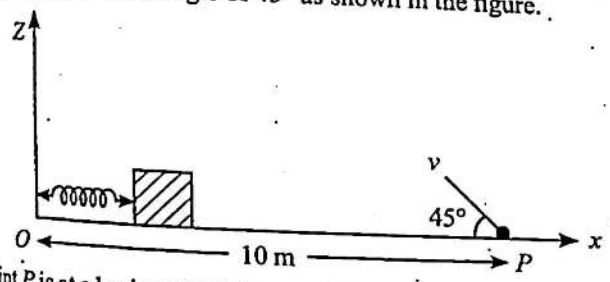
(a) $x_0 = \frac{4Mg}{k}$

(b) When spring achieves an extension of $x_0/2$ for the first time, the speed of the block connected to the spring is $3g\sqrt{\frac{M}{5k}}$

(c) $a_2 - a_1 = a_1 - a_3$

(d) At an extension of $x_0/4$ of the spring, the magnitude of acceleration of the block connected to the spring is $\frac{3g}{10}$

19. A small block is connected to one end of a massless spring of unstretched length 4.9 m. The other end of the spring (see the figure) is fixed. The system lies on a horizontal frictionless surface. The block is stretched by 0.2 m and released from rest at $t = 0$. It then executes simple harmonic motion with angular frequency $\omega = \pi/3$ rad/s. Simultaneously at $t = 0$, a small pebble is projected with speed v from point P at an angle of 45° as shown in the figure.

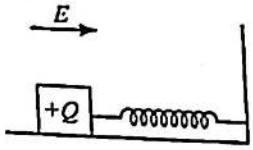


Point P is at a horizontal distance of 10 m from O. If the pebble hits the block at $t = 1$s, the value of v is ? (take, $g = 10$ m/s²)

C-16.21,W-28.42 UA-55.37 (IIT-JEE 2012)

(a) $\sqrt{50}$ m/s (b) $\sqrt{51}$ m/s (c) $\sqrt{52}$ m/s (d) $\sqrt{53}$ m/s

30. A wooden block performs SHM on a frictionless surface with frequency ν_0. The block carries a charge $+Q$ on its surface. If now a uniform electric field E is switched-on as shown, then the SHM of the block will be **(IIT-JEE 2011)**



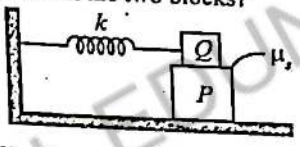
(a) Of the same frequency and with shifted mean position

(b) Of the same frequency and with the same mean position

(c) Of changed frequency and with shifted mean position

(d) Of changed frequency and with the same mean position

31. A block P of mass m is placed on a horizontal frictionless plane. A second block of same mass m is placed on it and is connected to a spring of spring constant k, the two blocks are pulled by a distance A. Block Q oscillates without slipping. What is the maximum value of frictional force between the two blocks? **(IIT-JEE 2004)**



(a) $kA/2$ (b) kA (c) $\mu_s mg$ (d) Zero

32. One end of a long metallic wire of length L is tied to the ceiling. The other end is tied to a massless spring of spring constant k. A mass m hangs freely from the free end of the spring. The area of cross-section and the Young's modulus of the wire are A and Y respectively. If the mass is slightly pulled down and released, it will oscillate with a time period T equal to **(IIT-JEE 1993)**

(a) $2\pi\sqrt{\frac{m}{k}}$ (b) $2\pi\sqrt{\frac{m(YA+Lk)}{YAk}}$

(c) $2\pi\sqrt{\frac{mYA}{kL}}$ (d) $2\pi\sqrt{\frac{mL}{YA}}$

Multiple Correct

33. A block with mass M is connected by a massless spring with stiffness constant k to a rigid wall and moves without friction on a horizontal surface. The block oscillates with small amplitude A about an equilibrium position x_0. Consider two cases: (*i*) when the block is at x_0 and (*ii*) when the block is at $x = x_0 + A$. In both the cases, a particle with mass m ($<M$) is softly placed on the block after which they stick to each other. Which of the following statement(s) is (are) true about the motion after the mass m is placed on the mass M?

C-4.36 W-15.36 UA-47.5 PC-32.78 (JEE Adv. 2016)

(a) The amplitude of oscillation in the first case changes by a factor of $\sqrt{\frac{M}{(m+M)}}$, whereas in the second case it remains unchanged

(b) The final time period of oscillation in both the cases is same

(c) The total energy decreases in both the cases

(d) The instantaneous speed at x_0 of the combined masses decreases in both the cases

@MAKE CBSE X GRW_EDUNET

34. A particle of mass m is attached to one end of a massless spring of force constant k, lying on a frictionless horizontal plane. The other end of the spring is fixed. The particle starts moving horizontally from its equilibrium position at time $t = 0$ with an initial velocity u_0. When the speed of the particle is $0.5u_0$, it collides elastically with a rigid wall. After this collision

C-21.77 W-73.71 UA-4.52 (JEE Adv. 2013)

(*a*) The speed of the particle when it returns to its equilibrium position is u_0

(*b*) The time at which the particle passes through the equilibrium position for the first time is $t = \pi\sqrt{\frac{m}{k}}$

(*c*) The time at which the maximum compression of the spring occurs is $t = \frac{4\pi}{3}\sqrt{\frac{m}{k}}$

(*d*) The time at which the particle passes through the equilibrium position for the second time is $t = \frac{5\pi}{3}\sqrt{\frac{m}{k}}$

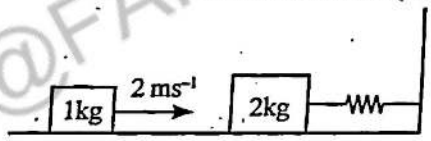
Numerical Type/Integer Type

35. On a frictionless horizontal plane, a bob of mass $m = 0.1$ kg is attached to a spring with natural length $l_0 = 0.1$ m. The spring constant is $k_1 = 0.009$ Nm^{-1} when the length of the spring $l > l_0$ and is $k_2 = 0.016$ Nm^{-1} when $l < l_0$. Initially the bob is released from $l = 0.15$ m. Assume that Hooke's law remains valid throughout the motion. If the time period of the full oscillation is $T = (n\pi)$ s, then the integer closest to n is_____.

C-8.92 W-17.16 UA-73.92 (JEE Adv. 2022)

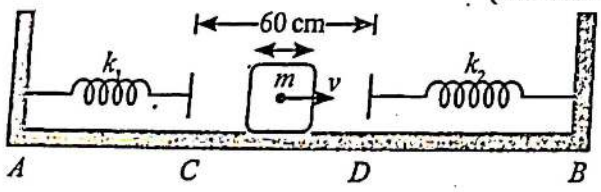
36. A spring block system is resting on a frictionless floor as shown in the figure. The spring constant is 2.0 Nm^{-1} and the mass of the block is 2 kg. Ignore the mass of the spring. Initially, the spring is in an unstretched condition. Another block of mass 1.0 kg moving with a speed of 2.0 ms^{-1} collides elastically with the first block. The collision is such that the 2.0 kg block does not hit the wall. The distance, in meters, between the two blocks when the spring returns to its unstretched position for the first time after the collision is

C-22.19 W-58.72 UA-19.09 (JEE Adv. 2018)



Two light springs of force constants k_1 and k_2 and a block of mass m are in one line AB on a smooth horizontal table such that one end of each spring is fixed on rigid supports and the other end is free as shown in the figure. The distance CD between the free ends of the spring is 60 cm. If the block moves along AB with a velocity 120 cm/s in between the springs, calculate the period of oscillation of the block. (Take, $k_1 = 1.8$ N/m, $k_2 = 3.2$ N/m, $m = 200$g)

(IIT-JEE 1985)



Match the Column

38. Column-I describes some situations in which a small object moves. Column-II describes some characteristics of these motions. Match the situations in Column-I with the characteristics in Column-II.

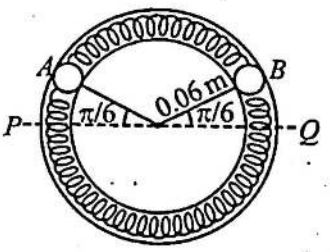
(IIT-JEE 2007)

	Column-I		Column-II
A.	The object moves on the x-axis under a conservative force in such a way that its speed and position satisfy $v = c_1\sqrt{(c_2 - x^2)}$, where c_1 and c_2 are positive constants.	p.	The object executes a simple harmonic motion.
B.	The object moves on the x-axis is in such a way that its velocity and its displacement from the origin are satisfied, $v = -kx$ which is a positive constant.	q.	The object does not change its direction.
C.	The object is attached to one end of a massless spring of a given spring constant. The other end of the spring is attached to the ceiling of an elevator. Initially everything is at rest. The elevator starts going upwards with a constant acceleration a. The motion of the object is observed from the elevator during the period it maintains this acceleration.	r.	The kinetic energy of the object keeps on decreasing.
D.	The object is projected from the earth's surface vertically upwards with a speed $2\sqrt{(GM_e)/R_e}$, where M_e is the mass of the earth and R_e is the radius of the earth. Neglect forces from objects other than the earth.	s.	The object can change its direction only once.

Subjective

39. Two identical balls A and B, each of mass 0.1 kg, are attached to two identical massless springs. The spring-mass system is constrained to move inside a rigid smooth pipe bent in the form of a circle as shown in figure. The pipe is fixed in a horizontal plane. The centers of the balls can move in a circle of radius 0.06 m. Each spring has a natural length of 0.06 πm and spring constant 0.1 N/m. Initially both the balls are displaced by an angle $\theta = \pi/6$ rad with respect to the diameter PQ of the circle (as shown in figure) and released from rest.

(IIT-JEE 1993)



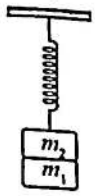
(*a*) Calculate the frequency of oscillation of ball B.

(*b*) Find the speed of ball A when A and B are at the two ends of the diameter PQ.

(*c*) What is the total energy of the system?

@FAKE_COPY_ONLY_FOR_STUDENT

40. Two masses m_1 and m_2 are suspended together by a massless spring of spring constant k (Fig.). When the masses are in equilibrium, m_1 is removed without disturbing the system. Find the angular frequency and amplitude of oscillation of m_2. **(IIT-JEE 1981)**



Pendulum

Single Correct

41. A 0.1 kg mass is suspended from a wire of negligible mass. The length of the wire is 1 m and its cross-sectional area is 4.9×10^{-7} m^2. If the mass is pulled a little in the vertically downward direction and released, it performs simple harmonic motion of angular frequency 140 rads^{-1}. If the Young's modulus of the material of the wire is $n \times 10^9$ Nm^{-2}, the value of n is **(IIT-JEE 2010)**

(a) $n = 1$ (b) $n = 2$ (c) $n = 4$ (d) $n = 3$

42. A simple pendulum has a time period T_1. The point of suspension is now moved upward according to the relation $y = kt^2$, ($k = 1$ m/s^2), where y is the vertical displacement. The time period now becomes T_2. The ratio $\frac{T_1^2}{T_2^2}$ is (Take, $g = 10$ m/s^2) **(IIT-JEE 2005)**

(a) $\frac{6}{5}$ (b) $\frac{5}{6}$ (c) 1 (d) $\frac{4}{5}$

43. The period of oscillation of simple pendulum of length L suspended from the roof of the vehicle which moves without friction, down an inclined plane of inclination α, is given by **(IIT-JEE 2000)**

(a) $2\pi\sqrt{\frac{L}{g\cos\alpha}}$ (b) $2\pi\sqrt{\frac{L}{g\sin\alpha}}$

(c) $2\pi\sqrt{\frac{L}{g}}$ (d) $2\pi\sqrt{\frac{L}{g\tan\alpha}}$

44. A highly rigid cubical block A of small mass M and side L is fixed rigidly on to another cubical block B of the same dimensions and of low modulus of rigidity η such that the lower face of A completely covers the upper face of B. The lower face of B is rigidly held on a horizontal surface. A small force F is applied perpendicular to one of the side faces of A. After the force is withdrawn, block A executes small oscillations, the time period of which is given by **(IIT-JEE 1992)**

(a) $2\pi\sqrt{ML\eta}$ (b) $2\pi\sqrt{\frac{M\eta}{L}}$ (c) $2\pi\sqrt{\frac{ML}{\eta}}$ (d) $2\pi\sqrt{\frac{M}{\eta L}}$

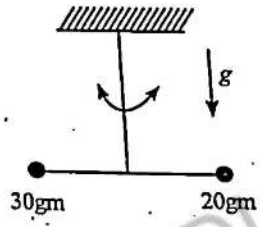
45. A thin fixed ring of radius 1 m has a positive charge 1×10^{-5} C uniformly distributed over it. A particle of mass 0.9 g and having a negative charge of 1×10^{-6} C is placed on the axis at a distance of 1 cm from the centre of the ring. Show that the motion of the negatively charged particle is approximately simple harmonic. Calculate the time period of oscillations. **(IIT-JEE 1982)**

(a) 0.5 secs (b) 9.28 secs (c) 0.628 sec (d) 0.1 sec

Numerical Type/Integer Type

46. Two point-like objects of masses 20 gm and 30 gm are fixed at the two ends of a rigid massless rod of length 10 cm. This system is suspended vertically from a rigid ceiling using a thin wire attached to its center of mass, as shown in the figure. The resulting torsional pendulum undergoes small oscillations. The torsional constant of the wire is 1.2×10^{-8} N m rad^{-1}. The angular frequency of the oscillations is $n \times 10^{-3}$ rad s^{-1}. The value of n is _____.

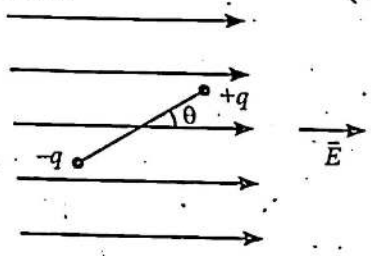
C-6.86 W-60.62 UA-32.52 (JEE Adv. 2023)



47. A mass M attached to a spring oscillates with a period of 2s. If the mass is increased by 2 kg the period increases by one sec. Find the initial mass M assuming that Hooke's law is obeyed. **(IIT-JEE 1979)**

Subjective

48. A point particle of mass M is attached to one end of a massless rigid non-conducting rod of length L. Another point particle of the same mass is attached to the other end of the rod. The two particles carry charges $+q$ and $-q$ respectively. This arrangement is held in a region of a uniform electric field E such that the rod makes a small angle θ (say of about 5 degrees) with the field direction. Find an expression for the minimum time needed for the rod to become parallel to the field after it is set free. **(IIT-JEE 1989)**



49. A point mass m is suspended at the end of massless wire of length L and cross-sectional area A. If Y is the Young's modulus of elasticity of the material of the wire, obtain the expression for the frequency of the simple harmonic motion along the vertical line. **(IIT-JEE 1978)**

@TAKE-CBSE-X @RAJEDUNET

ANSWER KEY

JEE-Main

1. [12]	2. [2]	3. [7]	4. [3]	5. [10]	6. [2]	7. [17]	8. [22]	9. (a)	10. (a)
11. (b)	12. (d)	13. (b)	14. (a)	15. [120]	16. [88]	17. [40]	18. (b)	19. (d)	20. [1]
21. [700]	22. (b)	23. (a)	24. (a)	25. (b,d)	26. (d)	27. (a)	28. (a)	29. (c)	30. [2]
31. [3]	32. [1]	33. [6]	34. [2]	35. (a)	36. (c)	37. (b)	38. (c)	39. (c)	40. (a)
41. (b)	42. [9]	43. [6]	44. (c)	45. (c)	46. (d)	47. (d)	48. (d)	49. [8]	50. [4]
51. [2]	52. (d)	53. (b)	54. (d)	55. (a)	56. (b)	57. (a)	58. (*)	59. [12]	60. (b)
61. (c)	62. [5]	63. [1]	64. [20]	65. [20]	66. [67]	67. (b)	68. [2]	69. [6]	70. (b)
71. (c)	72. (a)	73. (c)	74. (a)	75. (d)	76. [10]	77. [2]	78. (c)	79. (c)	80. (c)
81. (c)	82. [99]	83. [10]	84. (c)	85. (a)	86. (c)	87. [5]	88. [5]	89. (a)	90. (d)
91. (c)	92. (d)	93. (b)	94. [7]	95. [2]	96. (a)	97. (c)	98. (a)	99. (d)	

JEE-Advanced

1. (b)	2. (d)	3. (c)	4. (a)	5. (b)	6. (b)	7. (b)	8. (a, d)	9. (a, b, d)	10. (c)
16. (b, d)	17. (a)	18. (d)	19. (a)	20. (b)	21. (c)	22. (a,c)	23. (b,c)		
24. (A → p, s; B → p, q, r, s; C → s; D → q)				25. (c)	26. (d)	27. (b)	28. (c)	29. (a)	30. (a)
32. (b)	33. (a,b,d)	34. (a,d)	35. [6]	36. [2.09]	37. [2.83]	38. (A → p; B → q, r; C → p; D → q, r)			31. (a)
42. (a)	43. (a)	44. (d)	45. (c)	46. [10]	47. [1.6]				41. (c)

EXPLANATIONS

JEE-Main

1. [12] $V_{max} = A\omega \Rightarrow 10 = 4\omega$

$\Rightarrow \omega = \frac{5}{2}$

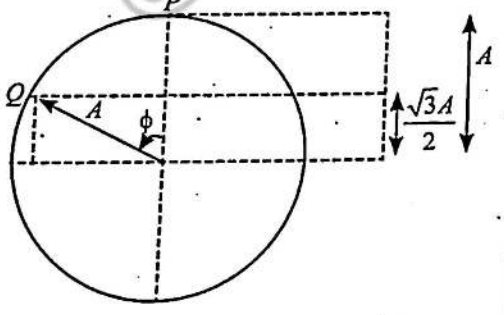
As, $v = \omega\sqrt{A^2 - x^2}$

$5 = \frac{5}{2}\sqrt{4^2 - x^2} \Rightarrow x^2 = 16 - 4$

$x = \sqrt{12}\,\text{cm}$

2. [2] Given an amplitude of simple harmonic oscillator

$= A$ Time period $= 6\pi$



From phasor diagram particle has to move from P to Q in a circle of radius equal to amplitude of SHM.

$\cos\phi = \frac{\frac{\sqrt{3}A}{2}}{A} = \frac{\sqrt{3}}{2}$

$\phi = \frac{\pi}{6}$

Now, $\frac{\pi}{6} = \omega t$

$\frac{\pi}{6} = \frac{2\pi}{T}t$

$\frac{\pi}{6} = \frac{2\pi}{6\pi}t$

$t = \frac{\pi}{2}$

So, $x = 2$

3. [7]

$v = \omega\sqrt{A^2 - x^2}$

at $x = \frac{2A}{3}$

$v = \omega\sqrt{A^2 - \left(\frac{2A}{3}\right)^2} = \frac{\sqrt{5}A\omega}{3}$

New amplitude of motion $= A'$

$v' = 3v = \sqrt{5}A\omega = \omega\sqrt{(A')^2 - \left(\frac{2A}{3}\right)^2}$

$A' = \frac{7A}{3}$

4. [3] $f_1 = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

For, $m = 9$ m

$f_2 = \frac{1}{2\pi}\sqrt{\frac{k}{9m}}$

Hence, $\frac{f_1}{f_2} = \sqrt{\frac{9}{1}} = \frac{3}{1}$

5. [10] $\because T = \frac{2\pi}{\omega}$

$3.14 = \frac{2\pi}{\omega} \Rightarrow \omega = 2\,\text{rad/s}$

Now, $x = 10\sin\left(\omega t + \frac{\pi}{3}\right)$

$\therefore v = \frac{dx}{dt} = 10\omega\cos\left(\omega t + \frac{\pi}{3}\right)$

Put $t = 0$ & $\omega = 2$

$v = 10\omega\cos\left(\frac{\pi}{3}\right) = 10 \times 2 \times \frac{1}{2} = 10\,m/s$

@FAKE_CBSE_A @RAJEDUNET

6. [2] Maximum velocity at mean position

$v_{max} = \omega A$

$\frac{2\pi}{T}A = \frac{2\times3.14}{3.14}\times0.06 = 0.12$ m/sec

$v_{max} = 12$ cm/sec

7. [17] Given, $x = 4$ m, $v = 2$ m/s, $a = 16$ m/s²

As, $|a| = \omega^2 x$

$\Rightarrow 16 = \omega^2(4) \Rightarrow \omega = 2$ rad/s

$v = \omega\sqrt{A^2 - x^2}$

$A = \sqrt{\frac{v^2}{\omega^2} + x^2} \Rightarrow A = \sqrt{\frac{4}{4} + 16}$

$A = \sqrt{17}$ m

8. [22] Here mass of the particle is 0.5 kg

$F = -50\,(x)$

$ma = (-50x)$

$0.5a = -50x$

$a = (-100x)$

$a = -\omega^2 x$

$\Rightarrow \omega^2 = 100 \Rightarrow (\omega = 10)$

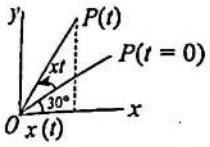
we know $T = \frac{2\pi}{\omega}$

$\Rightarrow T = \frac{2\pi}{10} = \left(\frac{\pi}{5}\right) = \frac{22}{7\times15} = \left(\frac{22}{35}\right)$

$\frac{\pi}{35} = \frac{22}{35} \Rightarrow x = 22$

9. (a) Given $\theta_1 = 30° = \frac{\pi}{6}$

At time t angle swept by point $P, \theta_2 = \omega t$



Projection on x-axis

$x(t) = r\cos(\theta_1 + \theta_2)$

$x(t) = r\cos(\omega t + \pi/6)$

10. (a) Restoring force $F = -kx$

$\therefore$ A is correct

Acceleration, $a = -\omega^2 x$

B is correct

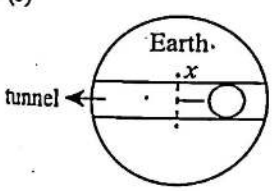
At mean position velocity is maximum

C is is correct

Acceleration is maximum at extreme points

D is incorrect

11. (b)



Let at some time the particle is at a distance x from the centre of Earth, then at that position gravitational field

$E = \frac{GM}{R^3}x$

$\vec{a} = -\frac{GM}{R^3}\vec{x} \Rightarrow \omega = \sqrt{\frac{GM}{R^3}} = \sqrt{\frac{g}{R}}$

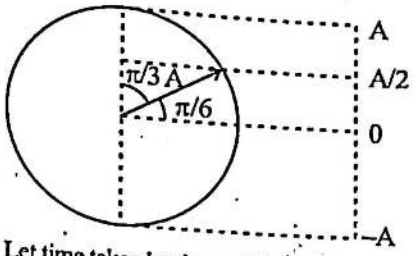
$\Rightarrow$ Acceleration of particle

$\because T = \frac{2\pi}{\omega} \Rightarrow T = 2\pi\sqrt{\frac{R}{g}}$

$\Rightarrow T = 2\times3.14\times\sqrt{\frac{6400\times10^3}{10}}$

$\Rightarrow T \approx 1$ hour 24 minutes

12. (d)



Let time taken by the particle to move from 0 to $\frac{A}{2}$ is t_1

& time taken by the particle to move from $\frac{A}{2}$ to A is t_2

$\Rightarrow \omega t_1 = \frac{\pi}{6}$ and $\omega t_2 = \frac{\pi}{3} \Rightarrow \frac{t_1}{t_2} = \frac{1}{2}$

$t_2 = 2t_1 = 2\times2 = 4$sec

13. (b) $y = \sin\omega t + \cos\omega t$

$y = \sin\omega t + \sin\left(\omega t + \frac{\pi}{2}\right)$

$\Delta\phi = \frac{\pi}{2} = 90°$

Amplitude of the motion,

$A = \sqrt{1^2 + 1^2 + 2\times1\times1\times\cos(90°)} = \sqrt{2}$

14. (a) $x = A\sin(\omega t + \delta)$

$\frac{A}{2} = A\sin(\omega t + \delta)$

At $t = 0$

$\sin\delta = \frac{1}{2} \Rightarrow \delta = \frac{\pi}{6}, \frac{5\pi}{6}$

For $\delta = \frac{5\pi}{6}$, velocity $\{A\omega\cos(\omega t + \delta)\}$ will be negative.

$\therefore$ Common solution is $\delta = \frac{\pi}{6}$

15. [120] $\because$ Resultant amplitude = amplitude of individual waves

$\Rightarrow 2A\cos\left(\frac{\Delta\phi}{2}\right) = A$

$\Rightarrow \cos\left(\frac{\Delta\phi}{2}\right) = \frac{1}{2} \Rightarrow \Delta\phi = 120°$

16. [88] $4V^2 = 50 - x^2$

$\Rightarrow V = \frac{1}{2}\sqrt{50 - x^2}$

Differentiating both sides

$a = \frac{-x}{4} \Rightarrow -\omega^2 x = \frac{-x}{4} \Rightarrow \omega = \frac{1}{2}$

$\because T = \frac{2\pi}{\omega} \Rightarrow T = 4\pi = \frac{88}{7}$

$x = 88$

17. [40]

$\because F = -kx \Rightarrow ma = -25x$

$\frac{1}{4}a = -25x; a = -100x$

$\therefore \omega^2 = 100$

$\Rightarrow \omega = 10$

Maximum speed, $v = \omega A$

$\Rightarrow 4 = 10\times A$

$\Rightarrow A = 0.4$ m

$\Rightarrow A = 40$ cm

18. (b) Velocity of a particle executing simple harmonic motion

$\Rightarrow v = \pm\omega\sqrt{A^2 - x^2}$

$\frac{v^2}{\omega^2} + x^2 = A^2 \Rightarrow \frac{v^2}{(\omega A)^2} + \frac{x^2}{A^2} = 1$

Elliptical

19. (d) $x = A\sin\omega t = A\sin\left[\left(\frac{2\pi}{T}\right)t\right]$

At, $t = 3$s; $x = \frac{A}{2}$

$\therefore \frac{A}{2} = A\sin\left(\frac{2\pi}{T}t\right)$

$\sin\frac{\pi}{6} = \sin\left(\frac{2\pi}{T}\times3\right)$ $T = \frac{6\pi}{\frac{\pi}{6}} = 36$ s

20. [1] Amplitude of the particle executing S.H.M

$A = 8$ cm

Time period, $T = 6$ sec

For S.H.M

$x = A\cos(\omega t)$

$\frac{A}{2} = A\cos\left(\frac{2\pi}{T}t\right) \Rightarrow \frac{1}{2} = \cos\left(\frac{2\pi}{T}\cdot t\right)$

@TAKE_CBSE_X @RAJ_EDUNET

$$\cos\frac{\pi}{3}=\cos\left(\frac{2\pi}{T}\cdot t\right)$$

$$\frac{\pi}{3}=\frac{2\pi}{T}\cdot t$$

$$t=\frac{T}{6}=\frac{6}{6}=1\text{s}.$$

21. [700] $A=10$ cm

$\therefore$ Total Energy $=1/2\,KA^2$.

By energy conservation, final v at $x=5$

$$\frac{1}{2}K(10)^2=\frac{1}{2}K(5)^2+\frac{1}{2}mv^2 \quad v=\sqrt{\frac{75K}{m}}$$

Now, velocity is tripled through external mean so the amplitude of SHM will change and so the total energy, (but potential energy at this moment will remain same)

$$\therefore\frac{1}{2}K(5)^2+\frac{1}{2}m\left(3\sqrt{\frac{75K}{m}}\right)^2=\frac{1}{2}KA^2$$

$$\Rightarrow 25K+675K=KA^2$$

$$\therefore A=\sqrt{700}$$

$$\therefore x=700$$

22. (*b*) We know that for SHM, potential energy is minimum of mean position and is maximum at its extreme position. Also, the sign of potential energy is the same throughout the SHM.

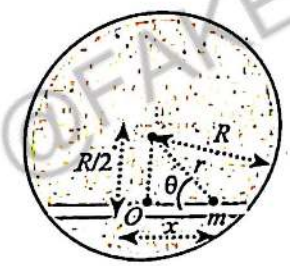
23. (*a*) Force, $F=m\,E\cos\theta$

$$=m\left(\frac{GM}{R^3}\times r\right)\times\frac{x}{r}$$

$$=\frac{mgR^2}{R^3}\times x \qquad \left[g=\frac{GM}{R^2}\right]$$

$$ma=\frac{mg}{R}x\Rightarrow a=\frac{g}{R}x$$

Time period of SHM, $T=2\pi\sqrt{\frac{R}{g}}$



$O\Rightarrow$ Mean Position

24. (*a*) $v=\omega\sqrt{A^2-x^2}$

$$\frac{v^2}{A^2\omega^2}+\frac{x^2}{A^2}=1$$

The graph of velocity is a function of displacement. Hence path will be ellipse.

25. (*b,d*) General equation of SHM

$$x=A\sin\left(\omega t\pm\phi\right)$$

We know, $\omega=\frac{2\pi}{T}$

Given, $T=\frac{\pi}{\omega}$

$$\therefore\ \omega'=\frac{2\pi}{\frac{\pi}{\omega}}=2\omega$$

$\therefore$ Equation becomes,

$x=a\sin(2\omega t\pm\phi)$

Here coefficient of t is 2ω.

26. (*d*) When a particle executes SHM, the nature of graphical representation of velocity as a function of displacement is elliptical.

27. (*a*) As we know that, $v^2=\omega^2(A^2-x^2)$ for SHM

$$\therefore v_1^2=\omega^2(A^2-x_1^2) \qquad ...(I)$$

$$v_2^2=\omega^2(A^2-x_2^2) \qquad ...(II)$$

Subtracting equation (*II*) from equation (*I*), we get

$$v_1^2-v_2^2=\omega^2(x_2^2-x_1^2)\Rightarrow\omega=\sqrt{\frac{v_1^2-v_2^2}{x_2^2-x_1^2}}$$

$$\Rightarrow T=\frac{2\pi}{\omega}\Rightarrow T=2\pi\sqrt{\frac{x_2^2-x_1^2}{v_1^2-v_2^2}}$$

28. (*a*) At $t=0$

$$A\sin(\omega t+\phi_0)=A/2$$

$$\Rightarrow\phi_0=\frac{\pi}{6},\frac{5\pi}{6}$$

Since it is moving in $-x$ direction:

$$\phi_0=\frac{5\pi}{6}$$

29. (*c*) $\omega=\dfrac{\frac{\pi}{6}}{0.1}=\dfrac{10\pi}{6}$

$$F=m\omega^2x$$

$$\frac{F}{m}=\frac{100\pi^2}{36}\times0.36=9.87N$$

30. [2] We have given, $x_1=5\sin\left(2\pi t+\frac{\pi}{4}\right)$

$$x_2=5\sqrt{2}\left(\sin2\pi t+\cos2\pi t\right)=10\sin\left(2\pi t+\frac{\pi}{4}\right)$$

$$\therefore x_{2,max}=2x_{1,max}$$

Hence, amplitude of second motion is two times the amplitude in first motion.

31. [3] Maximum speed

$$v=\omega\sqrt{A^2-a^2}$$

$$\frac{A\omega}{2}=\omega\sqrt{A^2-a^2}$$

$$\frac{A^2}{4}=A^2-a^2$$

$$a^2=A^2-\frac{A^2}{4}=\frac{3A^2}{4}$$

$$a=\frac{\sqrt{3}A}{2}\Rightarrow x=3$$

32. [1] It is given that, amplitude of $y_1=A_1$ is 1

Therefore, amplitude of

$$y_2=A_2=\sqrt{(5)^2+(5\sqrt{3})^2}=\sqrt{100}=10$$

$$\Rightarrow\frac{A_1}{A_2}=\frac{10}{10}=1$$

Hence, the correct value of x in $x=1$ is 1.

33. [6] While the particle moves from mean position to half of its amplitude, its phase changes by $\frac{\pi}{6}$ rad.

$$\therefore\ \frac{2\pi}{T}t=\frac{\pi}{6}\Rightarrow\frac{2}{2}t=\frac{1}{6}\Rightarrow t=\frac{1}{6}s.$$

Hence, $a=6$.

34. [2] Displacement, $x=A\sin(\omega t+\phi)$

Velocity, $=A\omega\cos(\omega t+\phi)$

At $t=0$

$$\Rightarrow 2=A\sin\phi$$

$$2\omega=A\omega\cos\phi$$

Solving (i) and (ii) we get

$$\Rightarrow\tan\phi=1$$

$$\Rightarrow\phi=45°$$

Putting ϕ in equation (i)

$$\Rightarrow 2=A\sin45°\Rightarrow A=2\sqrt{2}\text{ cm}\Rightarrow x=2$$

Hence, value of x is 2

35. (*a*) $\omega=\sqrt{\frac{k}{m}}\Rightarrow\omega\propto\frac{1}{\sqrt{m}}$

$$\Rightarrow\frac{\omega'}{\omega}=\sqrt{\frac{m}{m/2}}\Rightarrow\omega'=\sqrt{2}\omega$$

$\because v_{max}=v'_{max}$

$$A'\omega'=A\omega\Rightarrow A'=A\,\frac{\omega}{\omega'}$$

$$\Rightarrow A'=A\,\frac{\omega}{\sqrt{2}\omega}$$

$$A'=\frac{A}{\sqrt{2}}\Rightarrow fA=\frac{A}{\sqrt{2}}\Rightarrow f=\frac{1}{\sqrt{2}}$$

36. (*c*) At $t=\frac{3T}{4}$, particle is at mean position

$$\Rightarrow\text{Force}=0$$

At $t=T$, particle is at extreme position

$\Rightarrow$ Acceleration is maximum

At $t=\frac{T}{4}$, particle is at mean position

$\Rightarrow$ Speed is maximum

At $t=\frac{T}{2}$, particle is at extreme position

$\Rightarrow$ Speed $=0\Rightarrow$ K.E. $=0$

$\Rightarrow$ P.E. is maximum.

@FAKE_CBSE_X @RAJ_EDUNET

37. (b) $T = 2\pi\sqrt{\frac{I}{Mgd}}$

$\frac{T_1}{T_2} = \sqrt{\frac{I_1}{I_2}}$

$I_1 = MR^2 + MR^2 = 2MR^2$

$I_2 = \frac{MR^2}{2} + MR^2 = \frac{3}{2}MR^2$

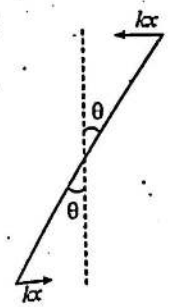
$\Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{2MR^2}{3MR^2/2}} = \sqrt{\frac{4}{3}} = \frac{2}{\sqrt{3}}$

38. (c) Torque on the loop, $\tau = MB\sin\theta = I\alpha$ [I is moment of inertia of the loop about its diameter]

$\pi R^2 IB\theta = \frac{mR^2}{2}\alpha$

$\omega = \sqrt{\frac{2\pi IB}{m}} = \frac{2\pi}{T}; \Rightarrow T = \sqrt{\frac{2\pi m}{IB}}$

39. (c)



Torque on rod at displacement θ from mean position θ is very small.

$x = \frac{L}{2}\theta$

$\tau = 2kx\frac{L}{2} = 2k\frac{L}{2}\frac{L}{4}\theta = \frac{kL^2}{2}\theta$

Now, $\tau = i\alpha$

$\frac{kL^2}{2}\theta = \frac{mL^2}{12}\alpha; \quad \alpha = \frac{6k}{m}\theta$

$\tau = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{6k}{m}}$

40. (a) $y = 5(\sin 3\pi t + \sqrt{3}\cos 3\pi t)$ cm

$\Rightarrow y = 10\sin(3\pi t + \frac{\pi}{3})$

$\Rightarrow A = 10$ cm

$\Rightarrow T = \frac{2}{3}$ sec

41. (b) $A\rho gx = F_{\text{restoring}}$

$\pi r^2\rho gx = m\omega^2 x$

$\therefore \omega = \sqrt{\frac{\pi r^2\rho g}{\rho v}}$

$= r\sqrt{\frac{\pi g}{v}} = 2.5\times10^{-2}\sqrt{\frac{3.14\times10}{310\times10^{-6}}}$

$= 2.5\times10^{-2}\times10^2\sqrt{10}$

$\omega = 2.5\times\sqrt{10}$

$\therefore f = \frac{2.5\times\sqrt{10}}{2\pi} = 1.25$ rad/sec

42. [9] Let total energy $= E = \frac{1}{2}KA^2$

$U = \frac{1}{2}K\left(\frac{A}{3}\right)^2 = \frac{KA^2}{2\times9} = \frac{E}{9}$

$KE = E - \frac{E}{9} = \frac{8E}{9}$

$\text{Ratio} = \frac{\text{Total Energy}}{KE} = \frac{E}{\frac{8E}{9}} = \frac{9}{8}$

$x = 9$

43. [6]

we have given that the mass of the particle is 0.2 kg

Total energy K.E. + P.E.

at $x = 0.04$ m, T.E. $= 0.5 + 0.4 = 0.9$ J

T.E $= 1\ m\omega^2A^2 = 0.9$

$= \frac{1}{2}\times0.2\left(2\pi\times\frac{25}{\pi}\right)^2\times A^2 = 0.9$

$\Rightarrow$ A $= 0.06$ m $\Rightarrow$ A $= 6$ cm

44. (c) Given, KE = PE

$\frac{1}{2}m\omega^2\left(A^2 - x^2\right) = \frac{1}{2}m\omega^2x^2$

$A^2 - x^2 = x^2 \Rightarrow A^2 = 2x^2$

$\Rightarrow x = \pm\frac{A}{\sqrt{2}}$

45. (c) $U_{max} = \frac{1}{2}m\omega^2\cdot A^2 = 25$ J

KE at $\frac{A}{2} = \frac{1}{2}m\omega^2\left(A^2 - \frac{A^2}{4}\right)$

$\Rightarrow$ KE $= \frac{3}{4}\left(\frac{1}{2}m\omega^2A^2\right)$

KE $= \frac{3}{4}\times25 = 18.75$ J

46. (d) $P.E. = \frac{1}{2}kx^2$

$K.E. = \frac{1}{2}k\left(A^2 - x^2\right)$

Given, $x = \frac{A}{2}$,

$\therefore \frac{P.E}{K.E} = \frac{x^2}{A^2 - x^2} = \frac{A^2}{4\left(\frac{3A^2}{4}\right)} = \frac{1}{3}$

47. (d) Kinetic energy of particle executing SHM

$\text{KE} = \frac{1}{2}m\omega^2\left(A^2 - x^2\right)$ ... (i)

At $x = 0$, KE is maximum while at $x = A$, KE is zero Also from (i) KE Vs x graph is parabola.

48. (d)

$K.E. = \frac{1}{2}m\omega^2(A^2 - x^2)$ $\rightarrow$ equation of downward parabola.

49. [8] $x = A\sin(\omega t)$

$U_{(x)} = \frac{1}{2}kx^2$

$\frac{dU}{dt} = \frac{1}{2}k2x\frac{dx}{dt}$

$= kA^2\omega\sin\omega t\cos\omega t\times\frac{2}{2}$

$\left(\frac{dU}{dt}\right)_{max} = \frac{kA^2\omega}{2}(\sin2\omega t)_{max}$

$2\omega t = \frac{\pi}{2} \Rightarrow t = \frac{\pi}{4}\omega = \frac{T}{8} \Rightarrow \beta = 8$

50. [4] General equation, $x = A\sin(\omega t + \phi)$ at given time

$\Rightarrow y = 40\times\frac{\sqrt{3}}{2} = 20\sqrt{3}$ cm

$\Rightarrow A = 40$ cm

$\Rightarrow K.E. = \frac{1}{2}k(A^2 - y^2) = 200$

$200 = \frac{1}{2}k\left(\frac{1600 - 1200}{100\times100}\right)$

$400\times100\times100 = k\times400$

$k = 10^4$

$x = 4$

51. [2] Given, $KE = PE + \frac{PE}{4}$ $KE = \frac{5}{4}PE$

$\Rightarrow \frac{1}{2}mW^2\left(A^2 - x^2\right) = \frac{5}{4}\cdot\frac{1}{2}mW^2x^2$

$\left[\because v = \omega\sqrt{A^2 - x^2}\right]$

$\Rightarrow A^2 - x^2 = \frac{5}{4}x^2 \Rightarrow \boxed{x = \frac{2}{3}A}$

$\therefore x = \frac{2}{3}\cdot3$ cm $\Rightarrow x = 2$ cm

52. (d) In simple harmoric motion, sum of K.E. and P.E. remains constant and <K.E.> = <P.E.> [for one time-period]

53. (b) Time period, $T = 2\pi\sqrt{\frac{m}{k}}$

$\Rightarrow 0.2 = 2\pi\sqrt{\frac{0.5}{k}} \Rightarrow k = 50\pi^2 = 500$

$x = A\sin\omega t$.

$\Rightarrow x = 5\sin\left(\omega\times\frac{T}{4}\right) = 5$ cm

$PE = \frac{1}{2}\times k\times x^2 = \frac{1}{2}\times500\times\left(\frac{5}{100}\right)^2 = 0.6255$

@FAKE_CBSE_X @RAJ_EDUNET

54. (*d*) Maximum energy = 10J

$$\frac{1}{2}Kx^2 = 10$$

$K = 5$

Given $T_{pendulum} = T_{spring}$

$$2\pi\sqrt{\frac{\ell}{g}} = 2\pi\sqrt{\frac{m}{K}} \Rightarrow \sqrt{\frac{4}{g}} = \sqrt{\frac{5}{5}}$$

$g = 4 m/s^2$

55. (*a*) Formula of total energy of a particle executing simple harmonic motion

$$E = \frac{1}{2}m\omega^2 a^2.$$

Given, $KE = \frac{3E}{4}$, therefore,

$$PE = E - \frac{3E}{4} = \frac{E}{4}$$

$$PE = \frac{1}{2}m\omega^2 y^2$$

$$\therefore \frac{E}{4} = \frac{1}{2}m\omega^2 y^2 \quad ...(ii)$$

Divide eq. (*i*) by eq. (*ii*), we get

$$4 = \frac{a^2}{y^2} \Rightarrow y = \pm\frac{a}{2}$$

56. (*b*) $K = \frac{1}{2}m\omega^2\left(A^2 - x^2\right)$

$$= \frac{1}{2}m\omega^2\left(A^2 - \frac{A^2}{4}\right) = \frac{1}{2}m\omega^2\left(\frac{3A^2}{4}\right)$$

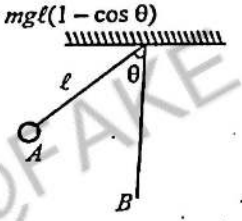
$$K = \frac{3}{4}\left(\frac{1}{2}m\omega^2 A^2\right)$$

57. (*a*) Maximum kinetic energy at lowest point B is given by

$K = mg\ell(1 - \cos\theta)$

Where θ = angular amp.

$K_1 = mg\ell(1 - \cos\theta)$



$K_2 = mg(2\ell)(1 - \cos\theta)$

$K_2 = 2K_1$

58. (*) Bonus

$$K = \frac{1}{2}mv^2;\ U = \frac{1}{2}kx^2 = \frac{1}{2}m^2x^2$$

$$\therefore \frac{K}{U} = \frac{v^2}{\omega^2x^2} = \left(\frac{\cos(\omega t)}{\sin(\omega t)}\right)^2$$

$$\therefore = \cot^2\left(\frac{\pi}{90}\times 210\right)$$

$$= \cot^2\left(2\pi + \frac{\pi}{3}\right) = \left(\frac{1}{\sqrt{3}}\right)^2 = \frac{1}{3}$$

59. [12] $k_{eq} = \frac{2k\cdot k}{3k} + k = \frac{5k}{3}$

Angular frequency of oscillation

$$\omega = \sqrt{\frac{k_{eq}}{m}} = \omega = \sqrt{\frac{5k}{3m}}$$

Period of oscillation $\tau = \frac{2\pi}{\omega}$

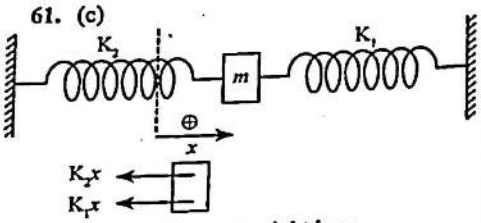
$$= 2\pi\sqrt{\frac{3m}{5k}} = \pi\sqrt{\frac{12m}{5k}}$$

60. (*b*) Angular frequency ω is given by,

$$\omega = \sqrt{\frac{k}{m}} \Rightarrow \omega \propto \frac{1}{\sqrt{m}}$$

$$\Rightarrow \frac{\omega_2}{\omega_1} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{1}{2}}$$

61. (c)



On displacing m to right by x

$$F = -(K_1x + K_2x) = -(5_1 + K_2)x$$

$$a = \frac{F}{m} = -\left(\frac{K_1 + K_2}{m}\right)x = -\omega^2 x$$

$$\therefore \omega = \sqrt{\frac{K_1 + K_2}{m}} \Rightarrow T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{K_1 + K_2}}$$

62. [5] As the spring are in parallel,

$$\omega = \sqrt{\frac{2k}{m}} = \sqrt{\frac{2\times 20}{2}}$$

$$= \sqrt{20} \text{ rad/s}$$

$$\therefore T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{20}} = \frac{\pi}{\sqrt{5}} \Rightarrow x = 5$$

63. [1] Initial time period $T = 2\pi\sqrt{\frac{m}{k}} = 1$

Time period when the mass is increased

$$T' = 2\pi\sqrt{\frac{m+3}{k}} = 2$$

$$\Rightarrow \frac{T}{T'} = \sqrt{\frac{m}{m+3}} = \frac{1}{2}$$

$$\Rightarrow m = 1$$

64. [20] Angular frequency

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{3.14} = 2 \text{rad/s}$$

maximum acceleration

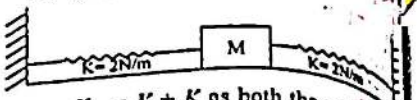
$a_{max} = A\omega^2 = 1 \times (2)^2 = 4\ m/s^2$

Maximum Force

$F_{max} = m\, a_{max}$

$= 5 \times 4 = 20\ N$

65. [20]



$K_{eff} = K + K$ as both the springs are parallel

$= 2K = 4$ N/m

$m = 0.49$

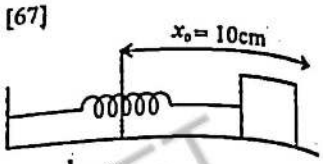
$$\because T = 2\pi\sqrt{\frac{m}{Kcff}} = 2\pi\sqrt{\frac{0.49\text{kg}}{4}}$$

$$\Rightarrow T. = 2\pi\sqrt{\frac{49}{400}} = \frac{7\pi}{10}$$

No. of oscillation in the 14π second

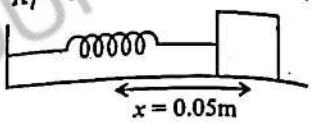
$$N = \frac{time}{T} = \frac{14\pi}{7\pi/10} = 20$$

66. [67]



$$U_i = \frac{1}{2}kx_0^2$$

$K_i = 0$



$$U_f = \frac{1}{2}k\left(\frac{x_0}{2}\right)^2$$

$K_f = 0.25J$

Using conservation of energy

$U_i + K_i = U_f + K_f$

$$\frac{1}{2}kx_0^2 + 0 = \frac{1}{2}k\frac{x_0^2}{4} + 0.25$$

$$\frac{1}{2}kx_0^2\frac{3}{4} = \frac{1}{4}$$

$$\frac{1}{2}k\frac{3}{100} = 1 \Rightarrow K = 67 N/m$$

67. (*b*) We know that, $\omega = \sqrt{\frac{k}{m}}$

$$V_{max_1} = V_{max_2} \Rightarrow A_1\omega_1 = A_2\omega_2$$

$$\frac{A_1}{A_2} = \frac{\omega_2}{\omega_1} = \sqrt{\frac{9k}{0.1}} \times \sqrt{\frac{0.05}{2k}}$$

$$\frac{A_1}{A_2} = \sqrt{\frac{9\times 0.05}{2\times 0.1}}$$

$$\therefore \frac{A_1}{A_2} = \frac{3}{2}$$

68. [2] For fig (a),

$$K_{eq} = \frac{k\times 2k}{k+2k} = \frac{2k}{3}$$

@FAKE_CBSE_@RALEDUNET

$T = 2\pi\sqrt{\frac{m}{k_{eq}}} = 2\pi\sqrt{\frac{3m}{2k}}$

For fig (b),

$k_{eq} = 3k$

So, $T' = 2\pi\sqrt{\frac{m}{3k}}$

Now, $\frac{T'}{T} = \sqrt{\frac{m\times 2k}{3k\times 3m}} = \frac{\sqrt{2}}{3}$

$\Rightarrow T' = \frac{\sqrt{2}}{3}\times 3 = \sqrt{2}\,s$ [$\because T = 3s$, given]

$\therefore x = 2$

69. [6] Time period of oscillation, will be given as

$T = \sqrt{\frac{m}{k_1}} + \pi\sqrt{\frac{m}{k_2}} = \pi\sqrt{\frac{0.1}{0.009}} + \pi\sqrt{\frac{0.1}{0.016}}$

$= \frac{\pi}{0.3} + \frac{\pi}{0.4} \Rightarrow T = 5.83\pi \approx 6\pi$

Thus, n = 6.

70. (b) In first case, velocity of block in equillibrium condition $v = A\omega = A\cdot\sqrt{\frac{k}{M}}$

In second case, velocity of block in equillibrium condition,

$v' = A'\omega' = A'\sqrt{\frac{k}{M+m}}$

Using conservation of momentum,

$Mv = (M+m)v'$

$\Rightarrow MA\sqrt{\frac{k}{M}} = (M+m)A'\sqrt{\frac{k}{M+m}}$

$\Rightarrow A' = A\sqrt{\frac{M}{M+m}}$

71. (c) Since, $k_{eq} = 2k$

$\therefore f = \frac{1}{2\pi}\sqrt{\frac{k_{eq}}{m}} = \frac{1}{2\pi}\sqrt{\frac{2k}{m}}$

72. (a) $T_1 = 2\pi\sqrt{\frac{m}{k}}$

$k_{eq} = \frac{K_1\times K_1}{K_1+K_1} = \frac{K_1}{2}$

$T_2 = 2\pi\sqrt{\frac{m}{(k/2)}} = 2\pi\sqrt{\frac{2m}{k}}$

$\Rightarrow \frac{T_2}{T_1} = \sqrt{2}\ and\ \frac{k_2}{k_1} = \frac{1}{2}$

73. (c) $x(t) = A\sin\omega t + B\cos\omega t$

$\Rightarrow x(t) = \sqrt{A^2+B^2}\,\sin(\omega t+\delta)$

$\Rightarrow v(t) = \omega\sqrt{A^2+B^2}\,\cos(\omega t+\delta)$

At $t = 0$:

$x(0) = \sqrt{A^2+B^2}\,\sin(\delta)$ ...(i)

$v(0) = \omega\sqrt{A^2+B^2}\,\cos(\delta)$ ...(ii)

Using eqn (i) and (ii)

$\Rightarrow (x(0))^2 + \left(\frac{v(0)}{\omega}\right)^2$

$= A^2 + B^2(\sin^2\delta + \cos^2\delta)$

$C = \sqrt{(x(0))^2 + \left(\frac{v(0)}{\omega}\right)^2}$

Using eqn (i) and (ii)

$\tan\delta = \frac{x(0)}{\frac{v(0)}{\omega}} = \frac{x(0)\omega}{v(0)}$

$\tan\phi = \tan\left(\frac{\pi}{2}-\delta\right) = \cot\delta = \frac{v(0)}{x(0)\omega}$

$\Rightarrow \phi = \tan^{-1}(\cot\delta) = \tan^{-1}\left(\frac{v(0)}{x(0)\omega}\right)$

74. (a) Equivalent spring constant $= 2k + 2k = 4k$

$T = 2\pi\sqrt{\frac{m}{4k}} = \pi\sqrt{\frac{m}{k}}$

75. (d) $\because V_{max} = A\omega$

Given, $\omega_1 A_1 = \omega_2 A_2$

We know that $\omega = \sqrt{\frac{K}{m}}$

$\therefore \sqrt{\frac{K_1}{m}}A_1 = \sqrt{\frac{K_2}{m}}A_2$

$\Rightarrow \frac{A_1}{A_2} = \sqrt{\frac{K_2}{K_1}}$

76. [10] Reduced mass of the system,

$\mu = \frac{m_1 m_2}{m_1+m_2}$

$\mu = \frac{0.2\times 0.8}{0.2+0.8} = 0.16kg$

Equivalent spring constant,

$K_{eq} = \frac{k\times 4k}{k+4k} = \frac{4k}{5} = 4\times\frac{20}{5} = 16$

$\omega = \sqrt{\frac{k_{eq}}{\mu}}$

$\omega = \sqrt{\frac{16}{0.16}} = 10\text{rad/s}$

77. [2] For Figure1, time period, $T_a = 2\pi\sqrt{\frac{m}{k}}$

For Figure-2, $K_{eq} = \frac{K_1\cdot K_2}{K_1+K_2} = \frac{K}{2}$

Therefore, time period, $T_b = 2\pi\sqrt{\frac{2m}{k}}$

$\Rightarrow \frac{T_b}{T_a} = \sqrt{2}$

78. (c) $y(t) = \frac{y_0}{2}(1-\cos 2\omega t)$

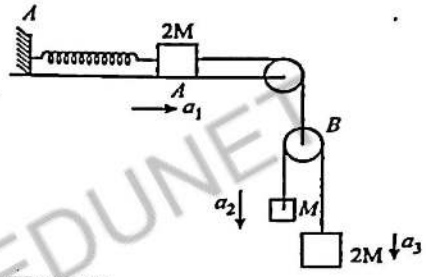
Amplitude $\frac{Mg}{k} = \frac{y_0}{2}$

$\Rightarrow \frac{k}{M} = \frac{2g}{y_0}$

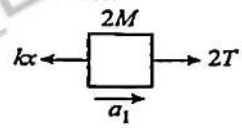
Angular frequency $2\omega = \sqrt{\frac{k}{m}}$

$\Rightarrow \omega = \frac{1}{2}\sqrt{\frac{k}{m}} = \frac{1}{2}\sqrt{\frac{2g}{y_0}} = \sqrt{\frac{g}{2y_0}}$

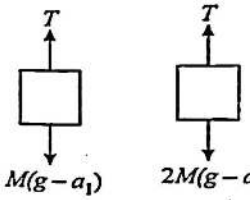
79. (c)



FBD of A:



FBD of other blocks in frame of pulley:



In the frame of pulley B, the hanging masses have accelerations:

$M \rightarrow (a_2 - a)$, $2M \rightarrow (a_3 - a_1)$: downward.

$\therefore (a_2 - a_1) = -(a_3 - a_1)$ [constant]

Assuming that the extension of the spring is x.

We consider the FBD of A:

$2Ma_1 = 2T - kx$

Upward acceleration of block M w.r.t. the pulley

B = Downward acceleration of block $2M$ w.r.t. the pulley

$\frac{T - M(g-a_1)}{M} = \frac{2M(g-a_1) - T}{2M}$

$\Rightarrow T = \frac{4M}{3}(g-a_1)$ ...(ii)

substituting in equation (i) we get

$2M.a_1 = \frac{8M}{3}(g-a_1) - kx$

@FAKE_CBSE_TG@RAJ_EDUNET

$$a_1 = \frac{8Mg - 3kx_0/4}{14m} = \frac{8g}{14} - \frac{3kx_0}{14m \times 4} = \frac{8g}{14} - \frac{3k}{14m} \times \frac{16Mg}{3k}$$

$$= \frac{8g}{14} - \frac{3g}{7} = \frac{8g}{14} - \frac{6g}{14} = \frac{2g}{14}$$

$$= \frac{g}{7} \text{ or } \frac{14m}{3} a_1 = -k\left[x - \frac{8mg}{3k}\right]$$

$$a_1 = -\frac{3k}{14m}\left[x - \frac{8mg}{3k}\right] \quad ...(iii)$$

that means, block 2m (connected with the spring) will perform SHM about $x_1 = \frac{8mg}{3k}$

Therefore, maximum elongation in the spring x_0

$$= 2x_1 = \frac{16mg}{3k}$$

On comparing equation (iii) with $a = -\omega^2(x - x_0)$ we get

$$\omega = \sqrt{\frac{3k}{14m}}$$

Now, at $\left(\frac{x_0}{2}\right)$, block will be passing through its mean position. Therefore speed is

$$= A\omega = \frac{8mg}{3k}\sqrt{\frac{3k}{14m}}$$

At, $\frac{x_0}{4}$ from equation (iii)

$$a = \frac{-3k}{14m}\left[\frac{4mg}{3k} - \frac{8mg}{3k}\right] = \frac{2g}{7}$$

80. (c) The time period of the simple pendulum,

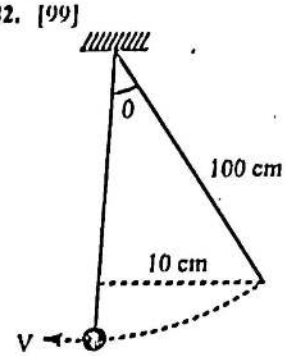
$$T_1 = 2\pi\sqrt{\frac{\ell}{GM}(2R)^2}$$

$$T_2 = 2\pi\sqrt{\frac{\ell}{GM}(3R)^2}$$

$$\therefore \frac{T_1}{T_2} = \frac{2}{3}$$

81. (c) $\because T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow T^2 \propto \ell$

82. [99]



Maximum tension occurs at mean position.

$$\Rightarrow T = mg + \frac{mv^2}{l}$$

From conservation of energy

$$\frac{1}{2}mv^2 = mgl(1 - \cos\theta)$$

$$\Rightarrow \frac{mv^2}{l} = 2mg(1 - \cos\theta)$$

$$\therefore T = mg + 2mg(1 - \cos\theta)$$

$$T = mg\left[1 + 2\left(1 - \sqrt{1 - \sin^2\theta}\right)\right]$$

$$T = mg\left[3 - 2\sqrt{1 - \frac{1}{100}}\right] \quad \left\{\because \sin\theta = \frac{1}{10}\right\}$$

$$T = 250 \times 10^{-3} \times 9.8\left[3 - 2\left(1 - \frac{1}{200}\right)\right] = \frac{99}{40}$$

$\therefore x = 99$

83. [10] For torsional pendulum, $T = 2\pi\sqrt{\frac{I}{C}}$

or $\frac{2\pi}{\omega} = 2\pi\sqrt{\frac{I}{C}}$

$$\therefore \omega = \sqrt{\frac{C}{I}}$$

Moment of inertia of the system,

$I = (30)(4)^2 + (20)(6)^2 = 1200$ gm-cm^2

$= 1.2 \times 10^{-4}$ kg-m^2.

$$\therefore \omega = \sqrt{\frac{1.2 \times 10^{-8}}{1.2 \times 10^{-4}}}$$

$\omega = (10^{-2}) = 10 \times 10^{-3}$ rad/s, $n = 10$

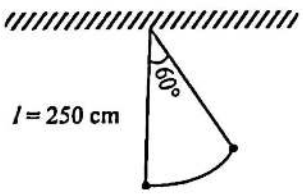
84. (c) $T \propto \frac{1}{\sqrt{g}}$

$$\therefore \frac{T'}{T} = \sqrt{\frac{g'}{g}} = \sqrt{\frac{g + g/6}{g}} \Rightarrow T' = \sqrt{\frac{6}{7}}\,T$$

85. (a) $g_{eff} = g\cos\alpha$, $T = 2\pi\sqrt{\frac{L}{g\cos\alpha}}$

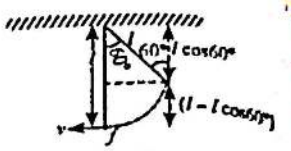
86. (c) We know that, $\omega = \sqrt{\frac{g}{\ell}}$

$$\therefore \omega = \pi = \sqrt{\frac{g}{\ell}} \Rightarrow \ell = \frac{g}{\pi^2} = \frac{9.8}{(3.14)^2} = 0.99395 \text{ m}$$



87. [5] From the conservation of mechanical Energy:

$$0 + mgl(1 - \cos 60°) = \frac{1}{2}mv^2 + 0$$



$$\Rightarrow v^2 = 2gl\left(\frac{1}{2}\right) = gl$$

$$v = \sqrt{10 \times \frac{25}{10}} = 5 \text{ m/s}$$

88. [5]

$$g_{eff} = g - \left(\frac{\rho_w}{\rho_b}\right)g \Rightarrow \frac{g}{g_{eff}} = 1 - \frac{1}{5}$$

$$T \propto \frac{1}{\sqrt{g}}$$

$$\therefore \frac{T'}{T} = \sqrt{\frac{g}{g_{eff}}} = \sqrt{\frac{5}{4}}$$

$$\Rightarrow T' = \sqrt{\frac{5}{4}} \times 10 = 5\sqrt{5} \text{ sec}$$

So, $x = 5$

89. (a) $T = 2\pi\sqrt{\frac{\ell}{g_{eff}}}$

When lift is stationary, then $g_{eff} = g$

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

When lift is moving up with acceleration g/2, then

$$g_{eff} = \frac{3g}{2}, \text{ so } T = 2\pi\sqrt{\frac{2\ell}{3g}} = \sqrt{\frac{2}{3}}T$$

90. (d) $\because$ Time period of pendulum

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

$$\therefore T \propto \sqrt{\ell}$$

Now $\frac{T_1}{T_2} = \sqrt{\frac{\ell_1}{\ell_2}} = \sqrt{\frac{\ell}{\ell/16}} = 4$

$$\therefore T_2 = \frac{T_1}{4} = \frac{T_0}{4}$$

91. (c) Given, $T = 2s$, $l = 2$ m

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$\Rightarrow 2 = 2\pi\sqrt{\frac{2}{g}} \Rightarrow g = 2\pi^2 \text{ m/s}^2$$

92. (d) Time period of simple pendulum

$$T = 2\pi\sqrt{\frac{l}{g_{eff}}}$$

When bob *is immersed in liquid*,

$= mg - \text{buoyant force}$

$\Rightarrow mg_{eff} = mg - v\sigma g$

$\therefore g_{eff} = 3g/4$

@FAKE_CBSE_X_BRAINEDUNET

Hence, $T' = 2\pi\sqrt{\frac{4\ell\times4}{3\times3g}} = 2\pi\frac{4}{3}\sqrt{\frac{\ell}{g}}$

Therefore, $T' = \frac{4}{3}T$

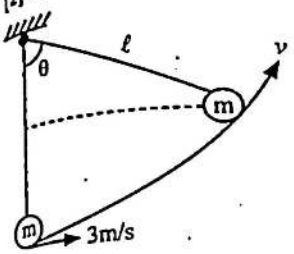
94. (b) Second pendulum has time period equal to 2 second. It take 1 second to move between extreme position.

95. [7] Total oscillation $= \frac{1}{2}+\frac{1}{8}=\frac{5}{8}$

Total time in oscillation $= \frac{T}{2}+\frac{T}{12}=\frac{7T}{12}$

$\therefore \frac{\alpha}{\beta}T = \frac{7}{12}T \Rightarrow \alpha = 7, \beta = 12$

96. [2] From conservation of Energy



$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mg\ell(1-\cos\theta)$

$\Rightarrow v^2 = u^2 - 2g\ell(1-\cos\theta)$

$\Rightarrow v^2 = 3^2 - 2\times10\times0.5\times\left(1-\frac{1}{2}\right)$

$\Rightarrow v^2 = 4$

$v = 2$m/s

96. (a) Angular frequency of pendulum

$\omega \propto \sqrt{\frac{g_{eff}}{\ell}}$

$\therefore \frac{\Delta\omega}{\omega} = \frac{1}{2}\frac{\Delta g_{eff}}{g_{eff}}$

$\Delta\omega = \frac{1}{2}\frac{\Delta g}{g}\times\omega$

[ω_s = angular frequency of support]

$\Delta\omega = \frac{1}{2}\times\frac{2A\omega^2}{10}$

$\Rightarrow \Delta\omega = 10^{-3}$ rad/s

97. (c) Case 1: Before collision,

Speed, $v = \sqrt{2gL(1-\cos\theta_0)}$

Case 2: After collision,

Speed, $v_1 = \sqrt{2gL(1-\cos\theta_1)}$

$\because \frac{v_1}{v} = \frac{M-m}{M+m}$

$\therefore \sqrt{\frac{1-\cos\theta_1}{1-\cos\theta_0}} = \frac{M-m}{M+m}$

$\frac{\sin(\theta_1/2)}{\sin(\theta_0/2)} = \frac{M-m}{M+m}$

$\left[\because 1-\cos2\theta = 2\sin^2\theta\right]$

$\frac{\theta_1}{\theta_0} = \frac{M-m}{M+m}$ [As angle is small]

$M\theta_1 + m\theta_1 = M\theta_0 - m\theta_0$

$M(\theta_0-\theta_1) = m(\theta_1+\theta_0)$

$M = m\left[\frac{\theta_1+\theta_0}{\theta_0-\theta_1}\right]$

98. (a) For a simple pendulum $T = 2\pi\sqrt{\frac{L}{g_{eff}}}$

Case 1: when pendulum is in air $\rightarrow g_{eff} = g$

Case 2: when pendulum is in liquid

$g_{eff} = g\left(1-\frac{\rho_{liquid}}{\rho_{body}}\right)$

$= g\left(1-\frac{1}{16}\right) = \frac{15g}{16}$

So, $\frac{T'}{T} = \frac{2\pi\sqrt{\frac{L}{15g/16}}}{2\pi\sqrt{\frac{L}{g}}} \Rightarrow T' = \frac{4T}{\sqrt{15}}$

99. (d) $\because g = \frac{GM}{R^2}$

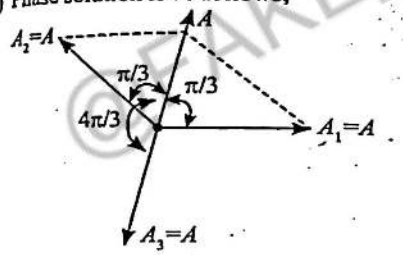
$\frac{g_p}{g_e} = \frac{M_p}{M_e}\left(\frac{R_e}{R_p}\right)^2 = 3\left(\frac{1}{3}\right)^2 = \frac{1}{3}$

Also, $T \propto \frac{1}{\sqrt{g}}$

$\Rightarrow \frac{T_p}{T_e} = \sqrt{\frac{g_e}{g_p}} = \sqrt{3} \Rightarrow T_p = 2\sqrt{3}$ s

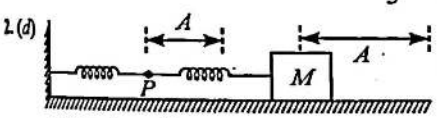
JEE-Advanced

1. (b) Phase solution is as follows,



And finding resultant we get the final has amplitude as A at an angle of $\frac{4\pi}{3}$.

2. (d)



As by above figure,

From A, A_3 should be directed opposite to this resultant and equal in magnitude.

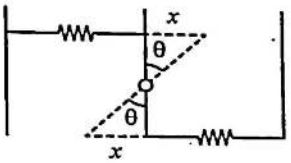
Let A_1 and A_2 be the maximum extension in the two springs or, $A_1 + A_2 = A$

$k_1A_1 = k_2A_2$

By solving these equations, we obtain

$x_1 = \left(\frac{k_2}{k_1+k_2}\right)A$

3. (c) $x = \frac{L}{2}\theta$



Restoring torque $= -(2kx)\cdot\frac{L}{2}$

$\alpha = -\frac{kL(L/2\theta)}{I} = -\left[\frac{kL^2/2}{ML^2/12}\right]\cdot\theta$

$= -\left(\frac{6k}{M}\right)\theta$

$f = \frac{1}{2\pi}\sqrt{\left|\frac{\alpha}{\theta}\right|} = \frac{1}{2\pi}\sqrt{\frac{6k}{M}}$

4. (a) Let the displacement be

$x = A\sin\omega t$

For $x = \frac{A}{2}$, $\omega t_1' = \frac{\pi}{6}$ and

For $x = A$, $\omega t_2' = \frac{\pi}{2}$

Time taken to go from

$x = \frac{A}{2}$ to $x = A$ is $t_2 = t'_2 - t_1$

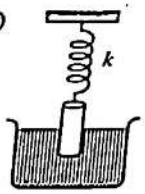
$= \left(\frac{1}{\omega}\right)\left(\frac{\pi}{2}-\frac{\pi}{6}\right) = \frac{\pi}{3\omega}$

Hence, $\frac{t_1}{t_2} = \frac{\pi/6\omega}{\pi/3\omega} = \frac{1}{2}$

$t_1 < t_2$

@FAKE_CBSE_X@RAJ_EDUNET

5. (b)



When the cylinder is displaced by an amount x from its mean position, both the spring force and upthrust will increase. Hence

Net resting force = extra spring force + extra or upthrust

or $F = -(kx + Ax\rho g)$

or $a = -\left(\frac{k + \rho Ag}{M}\right)x$

Now, $f = \frac{1}{2\pi}\sqrt{\left|\frac{a}{x}\right|} = \frac{1}{2\pi}\sqrt{\frac{k + \rho Ag}{M}}$

6. (b) As per the given question:

$v = \omega\sqrt{A^2 - x^2}$, to maximise $x = 0$

$(v_M)_{max} = (v_N)_{max}$

$\omega_M A_M = \omega_N A_N$

$\frac{A_M}{A_N} = \frac{\omega_N}{\omega_M} = \sqrt{\frac{k_2}{k_1}}$

7. (b) When the piston is in equilibrium the pressure inside = pressure just outside,

When the piston is displaced slightly by an amount x, there will be a change in volume

$dV = -Ax$

As, the cylinder is isolated from the surroundings, the process is adiabatic.

In adiabatic process,

$\frac{dp}{dV} = -\gamma\frac{p}{V}$

In an adiabatic process, there will be an increase in pressure inside the cylinder.

$$dp = -\frac{(\gamma p)}{V}(dV) = \gamma\left(\frac{p_0 + \frac{Mg}{A}}{V_0}\right)(Ax)$$

This increase in pressure, when multiplied by the cross-sectional area A, results in a net upward force, which is the restoring force. Hence,

$$F = -(dp)A = -\gamma\left(\frac{p_0A^2 + MgA}{V_0}\right)x$$

$$a = \frac{F}{M} = -\gamma\left(\frac{p_0A^2 + MgA}{V_0M}\right)x$$

$$f = \frac{1}{2\pi}\sqrt{\left|\frac{a}{x}\right|} = \frac{1}{2\pi}\sqrt{\frac{\gamma(p_0A^2 + MgA)}{V_0M}}$$

8. (a, d) Torque about a point O,

$\tau_A = \tau_B = \left(mg\frac{L}{2}\sin 0 + MgL\sin 0\right)$

And as we know

$\alpha = \frac{T}{I} = -\omega^2 0$

$I_A > I_B$ (Disc behaves like a point object at the end of rod in case B)

giving rise to $\omega_B > \omega_A$.

9. (a, b, d) For $A = -B$ and $C = 2B$

$X = B\cos^2\omega t + B\sin^2\omega t$

$= \sqrt{2}B\sin\left(2\omega t + \frac{\pi}{4}\right)$

So amplitude = $\sqrt{2}\,B$ in this case.

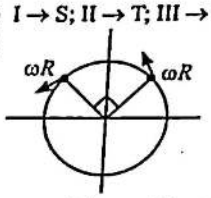
If $A = B$ and $C = 2B$ then $X = B + B\sin^2\omega t$

This is SHM about $X = B$.

It oscillates between $X = 0$ and $X = 2B$ with amplitude B.

10. (c) I → S; II → T; III → P; IV → R

(I)



$v_{res} = \sqrt{2}\omega R = \sqrt{2}$

I → S

(II) $v_A(t = 0.13) = \frac{5\pi}{\sqrt{2}}\cos 45\hat{i} + \left[\frac{5\pi}{\sqrt{2}} \times \frac{1}{\sqrt{2}} - g \times 0.1\right]\hat{j}$

$= \frac{5\pi}{2}\hat{i} + \left(\frac{5\pi}{2} - 1\right)\hat{j}$

$v_B(t = 0.1\text{sec}) = \frac{-5\pi}{2}\hat{i} + \left(\frac{5\pi}{2}\right)\hat{j}$

$v_{res} = \left|5\pi\hat{i} - \hat{j}\right|$

$= \sqrt{25\pi^2 + 1}$

II → T

(III) $x = x_A - x_B$

$= x_0\sin t - x_0\left(t + \frac{\pi}{2}\right)$

$= \sqrt{2}x_0\sin\left(t - \frac{\pi}{4}\right)$

$v_{rel} = \frac{dx}{dt} = \sqrt{2}x_0\cos\left(t - \frac{\pi}{4}\right)$

$= \sqrt{2}\cos\left(\frac{\pi}{3} - \frac{\pi}{4}\right)$

$= \sqrt{2} \times \frac{\sqrt{3} + 1}{2\sqrt{2}} = \frac{\sqrt{3} + 1}{2}$

III → P

(IV) $v_{rel} = \sqrt{3^2 + 1^2} = \sqrt{10}$

IV → R

11. As by figure.

Where A = amplitude

Velocity at any distance y is

$v = \omega\sqrt{A^2 - y^2}$

& Total height attained is

$h = y + \frac{v^2}{2g} = y + \frac{\omega^2(A^2 - y^2)}{2g}$

For h to be maximum $dh/dy = 0$

Putting $\frac{dh}{dy} = 0$, we get $y = \frac{g}{\omega^2} = y_{max}$

Since,

$y_{max} = y$ when $\frac{dh}{dy} = 0$

Therefore, $y_{max} = \frac{g}{\omega^2}$

since, $A\omega^2 > g$

$\Rightarrow A > \frac{g}{\omega^2} \Rightarrow A > y_{max}$

Therefore, $y_{max} = \frac{g}{\omega^2}$

12. Finding acceleration is one of the easiest way to calculate frequency.

Half of the volume of sphere is submerged

For equilibrium of sphere, weight = upthrust

$\therefore V\rho_s g = \frac{V}{2}(\rho_L)(g)$

$\rho_s = \frac{\rho_L}{2}$

When slightly pushed downward by x, increased upthrust restoring force.

= −(extra volume immersed) $(\rho_L)(g)$

or $ma = -(\pi R^2)x\,\rho_L g$ (a = acceleration)

$\therefore \frac{4}{3}\pi R^3\left(\frac{\rho_L}{2}\right)a = -(\pi R^2\rho_L g)x$

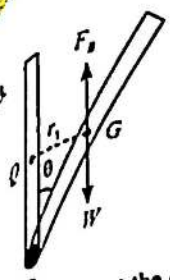
$\therefore a = -\left(\frac{3g}{2R}\right)x$

here we can see $a \propto -x$, motion is simple harmonic.

Frequency of oscillation, $f = \frac{1}{2\pi}\sqrt{\left|\frac{a}{x}\right|}$

$= \frac{1}{2\pi}\sqrt{\frac{3g}{2R}}$

@FAKE CBSE X @RAJEDUNET



Let S represent the cross-sectional area of the rod.

In the displaced position, as illustrated in the figure, F_B and W both pass through the center of gravity of the rod.

$W = V_1 d_2 g = SLd_2 g$

$F_B = V_1 d_1 g = SLd_1 g$

Given, $d_1 < d_2$

$\Rightarrow F_B > W$

Hence net force on rod,

$F_{net} = F_B - W = SLd_2 g - SLd_1 g$

$= SLg(d_2 - d_1)$

upwards,

The restoring torque of this force about point P is

$\tau = F \times r_{perpendicular}$

$\tau = SLg(d_2 - d_1) \times QG$

$\tau = -SLg(d_2 - d_1)\frac{L}{2}\sin\theta$

Since θ is very small,

$\Rightarrow \sin\theta = \theta$

$\tau = -SLg(d_2 - d_1)\frac{L}{2}\theta$ ...(i)

Hence motion of rod is simple harmonic,

But $\tau = I\frac{d^2\theta}{dt^2}$,

Where, I is moment of inertia of rod w.r.t. point P

$I = \frac{ML^2}{3} = \frac{SLd_1L^2}{3}$

Substitute the value of I in eqn. (i), we get,

$\frac{d^2\theta}{dt^2} = -\left(\frac{3}{2}g\frac{(d_2 - d_1)}{d_1 L}\right)\theta$

Compare this eqn. with standard SHM eqn.

$\frac{d^2\theta}{dt^2} = -\omega^2\theta$,

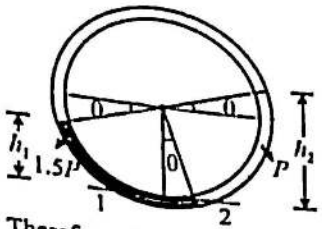
We get,

$\omega = \sqrt{\frac{3}{2}g\frac{(d_2 - d_1)}{d_1 L}}$

14. As per above statements,

For equilibrium the force should be zero here that means that the pressure at both points should be the same.

(a) In a state of equilibrium, the pressure of the same liquid at the same level will be equal.



Therefore, $P_1 = P_2$ or $P + (1.5\rho g h_1) = P + (\rho g h_2)$

(P = pressure of gas in empty part of the tube)

$\Rightarrow 1.5h_1 = h_2$

$\Rightarrow 1.5\,[R\cos\theta - R\sin\theta] = (R\cos\theta + R\sin\theta)$

or $3\cos\theta - 3\sin\theta = 2\cos\theta + 2\sin\theta$

or $5\tan\theta = 1$

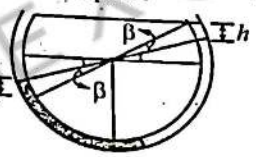
$\theta = \tan^{-1}\left(\frac{1}{5}\right)$

(b) When liquids get disturbed by an angle β.

Net restoring pressure

$\Delta p = 1.5\rho g h + \rho g h = 2.5\rho g h$

This pressure will be uniform across all sections of the liquid. Consequently, there will be a net restoring torque on the entire liquid.



$\tau = -(\Delta p)(A)(R)$

or $\tau = -2.5\rho g h\, AR$

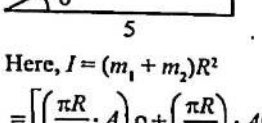
$= -2.5\rho g AR[R\sin(\theta + \beta) - R\sin\theta]$

$= -2.5\rho g AR^2[\sin\theta\cos\beta + \sin\beta\cos\theta - \sin\theta]$

For small angle $\cos\beta = 1$ and $\sin\beta = \beta$

$\therefore \tau = -(2.5\,\rho A g R^2\cos\theta)\beta$

or $I\alpha = -(2.5\,\rho A g R^2\cos\theta)\beta$ ...(i)



Here, $I = (m_1 + m_2)R^2$

$= \left[\left(\frac{\pi R}{2}\cdot A\right)\rho + \left(\frac{\pi R}{2}\right)\cdot A(1.5\rho)\right]R^2$

$= (1.25\pi R^3\rho)A$

and $\cos\theta = \frac{5}{\sqrt{26}} = 0.98$

on putting in Eq. (i), we have

$\alpha = -\frac{(6.11)\beta}{R}$

As angular acceleration is proportional to $-\beta$, motion is simple harmonic in nature.

$T = 2\pi\sqrt{\left|\frac{\beta}{\alpha}\right|} = 2\pi\sqrt{\frac{R}{6.11}}$

Hence,

(a) $0 = \tan^{-1}\left(\frac{1}{5}\right)$

(b) $2\pi\sqrt{\frac{R}{6.11}}$

15. On finding the amplitude of both the equations-

$A_1 = 10$ (directly)

For $A_2 : y_2 = 5\sin 3\pi t + 5\sqrt{3}\cos 3\pi t$

$= 5\sin 3\pi t + 5\sqrt{3}\sin\left(3\pi t + \frac{\pi}{2}\right)$

On superpositioning and calculating the resultant amplitude, we get

$A_2 = \sqrt{(5)^2 + (5\sqrt{3})^2} = 10$

$\frac{A_1}{A_2} = \frac{10}{10} = 1 = 1:1$

16. (b, d) As per question,

I[st] Particle,

$P = 0$ at $x = a$

$\Rightarrow$ 'a' represents the amplitude of oscillation

$a = A_1$(Say)

At $x = 0, P = b$

$\Rightarrow mv_{max} = b$

$v_{max} = \frac{b}{m}$

$E_1 = \frac{1}{2}mv_{max}^2 = \frac{m}{2}\left[\frac{b}{m}\right]^2 = \alpha x$

$= \frac{b}{m}\omega_1 = \frac{b}{ma} = \frac{1}{mn^2}\left(A_1 = a, \frac{a}{b} = n^2\right)$

II[nd] Particle

$P = 0$ at $x = R$

$\Rightarrow A_2 = R$

At

$x = 0, P = R$

$\Rightarrow v_{max} = \frac{R}{m}$

$E_2 = \frac{1}{2}mv_{max}^2 = \frac{m}{2}\left[\frac{R}{m}\right]^2 = \frac{R^2}{2m}$

$\Rightarrow A_2\omega_2 = \frac{R}{m}$

@TAKE CBSE A GRAJ EDUNET

$$\frac{\omega_2}{\omega_1}=\frac{1/m}{1/mn^2}=n^2$$

$$\frac{E_1}{\omega_1}=\frac{b^2/2m}{1/mn^2}=\frac{b^2n^2}{2}=\frac{a^2}{2n^2}=\frac{R^2}{2}$$

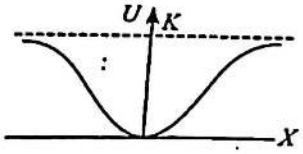
$$\frac{E_2}{\omega_2}=\frac{R^2/2m}{1/m}=\frac{R^2}{2}$$

$$\Rightarrow \frac{E_1}{\omega_1}=\frac{E_2}{\omega_2}$$

17. (*a*) At the mean location, P.E. is zero and at the extreme position, it is maximum. At $t=0$, $x=A$. As a result, P.E. is the maximum, and I is correct.
P.E. is minimum at $x=0$ in III. Thus this is accurate.

18. (*d*) Let's make a rough graph of potential energy.
At origin,

$$F=\frac{-dU}{dx}=-(\text{slope of } U-x \text{ graph})=0.$$



So origin will be the equilibrium position. The particle performs SHM about origin.
As
$F=0$ (at equilibrium as $x=0$)
U is minimum at $x=0$ and $U_{min}=0$
U is maximum $x\to\pm\infty$ and $U_{max}=k$
Therefore, it is unstable at far way points (equilibrium at x not equal to 0).
The particle oscillates about $x=0$ for small displacement from the origin and it is in stable equilibrium at the origin.

19. (*a*) As given in the question,
$U(x)=k|x|^3$,
But,

$$U=\frac{1}{2}mA^2\omega^2\sin^2\omega t$$

$$\Rightarrow \omega^2a^2=Cka^3 \text{ where } C=\text{constant}$$

$$\Rightarrow \omega=C\sqrt{a}$$

Therefore,

$$T=C\frac{1}{\sqrt{a}} \text{ where } C=\text{constant}$$

20. (*b*) By formula of frequency, $\nu=\frac{1}{2\pi}\sqrt{\frac{k}{m}}$

$$\Rightarrow \frac{25}{\pi}=\frac{1}{2\pi}\sqrt{\frac{k}{0.2}}$$

or $k=50\times50\times0.2=500$ N/m
If A represents the amplitude of oscillation

Total energy = KE + PE

$$\frac{1}{2}kA^2=0.5+0.4$$

$$A=\sqrt{\left(\frac{2\times0.9}{500}\right)}=0.06 \text{ m}$$

21. (*c*) You can find K.E. by
Total energy – Potential energy

$$\frac{1}{2}kA^2-\frac{1}{2}kx^2$$

We know that x is function of sin or cosine so $\sin^2x$ or $\cos^2x$ is the term that will be in K.E. equation.
Now we know that
$\cos(2x)=\cos^2x-\sin^2x$
$=2\cos^2x-1$
$=1-2\sin^2x$
So from here we can see $\cos(2\omega t)$ or $\sin(2\omega t)$ will appear in K.E. So we can see the frequency will be doubled.

22. (*a,c*) As by Superposition principle,
$y=y_1+y_2+y_3$
$=a\sin\omega t+a\sin(\omega t+45°)+a\sin(\omega t+90°)$
$=2a\sin(\omega t+45°)\cos45°+a\sin(\omega t+45°)$
$=\sqrt{2}\ a\sin(\omega t+45°)+a\sin(\omega t+45°)$
$=(\sqrt{2}+1)a\sin(\omega t+45°)$
And amplitude of resultant motion is $a(\sqrt{2}+1)$ and it differs by 45 degrees w.r.t. to 1st.
Energy in SHM $\propto$ (amplitude)^2

$$\left[E=\frac{1}{2}mA^2\omega^2\right]$$

$$\frac{E_{resultant}}{E_{single}}=\left(\frac{A}{a}\right)^2=(\sqrt{2}+1)^2=(3+2\sqrt{2})$$

$$E_{resultant}=(3+2\sqrt{2})E_{single}$$

23. (*b,c*)

$$k_{max}=\frac{1}{2}kA^2=\frac{1}{2}\times2\times10^6\times(10^{-2})^2=100 \text{ J}$$

$x=0$	$x=A$
$K=100$ J = Maximum	$K=0$ J = Minimum
$U=60$ J = Minimum	$U=160$ J = Maximum
$E=160$ J = constant	$E=160$ J = constant

24. (A → p, s; B → p, q, r, s; C → s; D → q)
Try to analyze the graphs if given.
A. The potential energy is at its lowest point when an object is at the mean position.
B. For $a=0$, $s=s_0+vt$ → option (q), (r)
For $a=$ constant, $s=ut+\frac{1}{2}at^2$ option (p) and (s)
C. $R=\frac{v^2\sin2\theta}{g}$
$\therefore R\propto v^2$ → option (s)
D. $T=2\pi\sqrt{\frac{I}{g}}$
$\therefore T^2\propto I$ → option (q)

25. (*c*) In SHM, KE = 0 in periodic;
If $E>V$ particle will escape.
$E>0$ for oscillation.
So, $V>E>0$.

26. (*d*) For $|x|>X_0$, potential energy is constant, kinetic energy will also remain constant. Which implies velocity is constant.
$\therefore$ Acceleration will be zero.

27. (*b*) Dimensional analysis can be done to solve it.

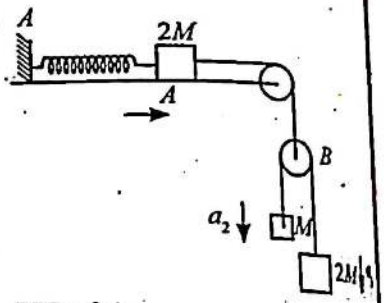
$$[\alpha]=\left[\frac{PE}{x^4}\right]=\left[\frac{ML^2T^{-2}}{L^4}\right]=[ML^{-2}T^{-2}]$$

$$\therefore \left[\frac{m}{\alpha}\right]=[L^2T^2]$$

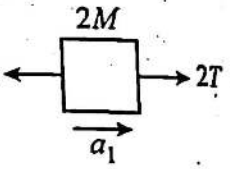
$$\Rightarrow \left[\frac{1}{A}\sqrt{\frac{m}{\alpha}}\right]=[T]$$

We compared the dimensions as we need the dimension of Time Period, it should be T.

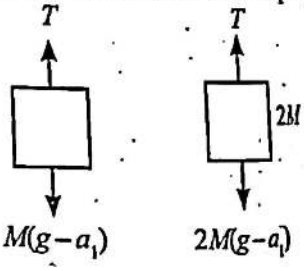
28. (*c*)



FBD of A:



FBD of other blocks in frame of pulley



@FAKE_CBSE_K @RAJEEDIXIT

In the frame of pulley B, the hanging masses have accelerations:

$M \rightarrow (a_2 - a_1)$, $2M \rightarrow (a_3 - a_1)$: downward.

$\therefore (a_2 - a_1) = -(a_3 - a_1)$ [constant]

Assuming that the extension of the spring is x

We consider the FBD of A:

$2Ma_1 = 2T - kx$

Upward acceleration of block M w.r.t. the pulley B = Downward acceleration of block $2M$ w.r.t. the pulley

$$\frac{T - M(g - a_1)}{M} = \frac{2M(g - a_1) - T}{2M}$$

$$\Rightarrow T = \frac{4M}{3}(g - a_1) \quad ...(ii)$$

substituting in equation (i) we get

$$2M.a_1 = \frac{8M}{3}(g - a_1) - kx$$

$$a_1 = \frac{8Mg - 3kx_0/4}{14M}$$

$$= \frac{8g}{14} - \frac{3kx_0}{14M \times 4}$$

$$= \frac{8g}{14} - \frac{3x}{14M \times 4} \times \frac{16Mg}{3x}$$

$$= \frac{8g}{14} - \frac{4g}{14} = \frac{8g}{14} = \frac{2g}{7}$$

$$\text{or } \frac{14M}{3}a_1 = -k\left[x - \frac{8Mg}{3k}\right]$$

$$a_1 = -\frac{3k}{14M}\left[x - \frac{8Mg}{3k}\right] \quad ...(iii)$$

that means, block 2 M (connected with the spring) will perform SHM about x_1

$$= \frac{8Mg}{3k}$$

Therefore, maximum elongation in the spring $x_0 = 2x_1 = \frac{16Mg}{3k}$

On comparing equation (iii) with $a = -\omega^2(x - x_0)$ we get

$$\omega = \sqrt{\frac{3k}{14M}}$$

Now, at $\left(\frac{x_0}{2}\right)$, block will be passing through its mean position. Therefore speed is

$$= A\omega = \frac{8Mg}{3k}\sqrt{\frac{3k}{14M}}$$

At, $\frac{x_0}{4}$ from equation (iii)

$$a = \frac{-3k}{14M}\left[\frac{4Mg}{3k} - \frac{8Mg}{3k}\right] = \frac{2g}{7}$$

29. (a) If it is hitting at $t = 1$ sec that means 1 sec should be its time of flight as the block is small so,

The spring's unstretched distance is 4.9 meters.

SHM angular frequency $\frac{\pi}{3}$ rad/s.

The angle of projection of pebble is 45°.

The force necessary to move a mass attached to a spring whose one end is fixed at a location is given by, according to Hooke's law.

$F = -kx$

$$1 = \frac{2v\sin\theta}{g}$$

$$v = \frac{10 \times 1}{2 \times \frac{1}{\sqrt{2}}} = 5\sqrt{2} \text{ m/s}$$

30. (a) Frequency depends on variable force and does not depend on constant external force. Here Uniform Electric field is the constant external force due to which only change in mean position occurs.

Initially mean position be x_0 is the natural length of spring

But in presence of E, mean position shift by x_0. The mean position becomes

$Kx_0 = QE$

$$x_0 = \frac{QE}{K}$$

31. (a) As the spring is connected to the upper block, the P–Q system oscillates with angular frequency ω.

Therefore,

$$\omega = \sqrt{\frac{k}{m+m}} = \sqrt{\frac{k}{2m}}$$

Maximum acceleration,

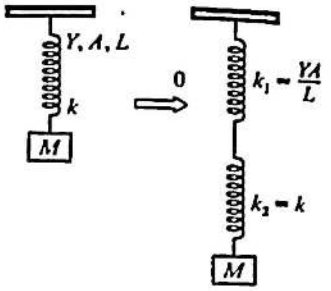
$$a = \omega^2 A \text{ or } \frac{k}{2m}A$$

The force of friction provides this acceleration of blocks and no relative motion if force is less than limiting force.

$$F = ma = m\left(\omega^2 A \text{ or } \frac{k}{2m}A\right) = \frac{kA}{2}$$

32. (b) Equivalent spring constant is

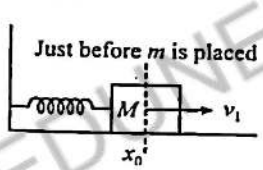
$$k_{eq} = \frac{k_1 k_2}{k_1 + k_2} = \frac{\frac{YA}{L}}{\frac{YA}{L} + k} = \frac{YAk}{YA + Lk}$$

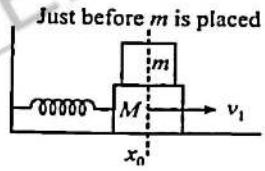


$$\therefore T = 2\pi\sqrt{\frac{m}{k_{eq}}} = 2\pi\sqrt{\frac{m(YA + Lk)}{YAk}}$$

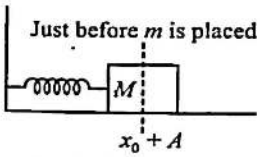
33. (a,b,d) Taking two cases and applying a conservation of linear momentum to them we get-

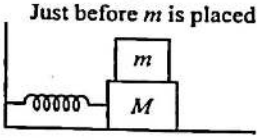
Case-1:





Case-2:





In Case-1,

$Mv_1 = (M + m)v_2$

$$v_2 = \left(\frac{M}{M+m}\right)v_1$$

$$\sqrt{\frac{k}{M+m}}A_2 = \left(\frac{M}{M+m}\right)\sqrt{\frac{k}{M}}A_1$$

$$A_2 = \sqrt{\frac{M}{M+m}}A_1$$

In Case-2,

$A_2 = A_1$

$T = 2\pi\sqrt{\frac{M+m}{k}}$ in both cases.

& $E_2 = E_1$

@FAKE_CBSE_@_EDUNET

The instantaneous speed at position x_0 decreases in both scenarios

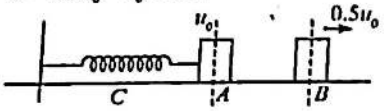
In the first case, the total energy decreases, while in the second case, it remains constant.

34. *(a,d)* At the equilibrium point ($t = 0$), the particle has its maximum velocity, denoted as u_0.

So, the velocity at time t can be represented as

$u = u_{max} \cos \omega t + u_0 \cos \omega t$

$u = 0.5\, u_0 = u_0 \cos \omega t$



$$\omega t = \frac{\pi}{3}$$

$$\frac{2\pi}{T} t = \frac{\pi}{3}$$

$$t = \frac{T}{6}$$

(b) $t = t_{AB} + t_{BA}$

$$= \frac{T}{6} + \frac{T}{6} = \frac{T}{3} = \frac{2\pi}{3}\sqrt{\frac{m}{k}}$$

(c) $t = t_{AB} + t_{BA} + t_{AC}$

$$= \frac{T}{6} + \frac{T}{6} + \frac{T}{4} = \frac{7}{12}T = \frac{7\pi}{6}\sqrt{\frac{m}{k}}$$

(d) $t = t_{AB} + t_{BA} + t_{AC} + t_{CA}$

$$= \frac{T}{6} + \frac{T}{6} + \frac{T}{4} + \frac{T}{4} = \frac{5}{6}T = \frac{5\pi}{3}\sqrt{\frac{m}{k}}$$

As, $\omega t_1 = \frac{\pi}{3}$

$$t_1 = \frac{\pi}{3\omega}$$

Once it returns to its equilibrium position at, $t_2 = 2t_1$ with same energy.

Its speed will be identical to the initial velocity. i.e., u_0.

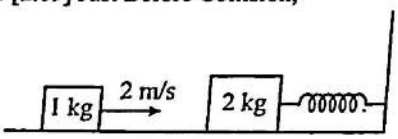
35. [6] Time period of oscillation, will be given as

$$T = \sqrt{\frac{m}{k_1}} + \pi\sqrt{\frac{m}{k_2}} = \pi\sqrt{\frac{0.1}{0.009}} + \pi\sqrt{\frac{0.1}{0.016}}$$

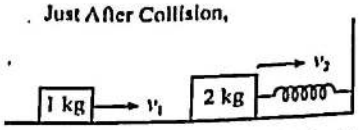
$$= \frac{\pi}{0.3} + \frac{\pi}{0.4} \Rightarrow T = 5.83\pi \approx 6\pi$$

Thus, $n = 6$.

36. [2.09] Just Before Collision,



Just After Collision,



The velocities of the 1 kg and 2 kg blocks immediately after the collision can be denoted as v_1 and v_2, respectively.

Applying the principle of momentum conservation, we have

$1 \times 2 = 1v_1 + 2v_2$ ...(*I*)

Since the collision is elastic, it follows that e equals 1 or, in other words, the relative velocity of separation is equal to the relative velocity of approach.

$v_2 - v_1 = 2$ ...(*II*)

using eqns. (*I*) and (*II*), we have

$$v_2 = \frac{4}{3}\text{ m/s},\ v_1 = \frac{-2}{3}\text{ m/s}$$

After the collision, the 2 kg block will undergo Simple Harmonic Motion (SHM).

$$t = \frac{T}{2} = \pi\sqrt{\frac{m}{k}} = 3.14\text{s}$$

Distance

$$= |v_1|\, t = \frac{2}{3} \times 3.14 = 2.093 = 2.09\text{ m}$$

37. [2.83]

Time period of oscillation from point C (as point C and D moves with constant speed with 120 cm/s) is

Therefore,

$$T = t_{CD} + \frac{T_2}{2} + t_{DC} + \frac{T_1}{2}$$

$$T_1 = 2\pi\sqrt{\frac{m}{k_1}} \text{ and } T_2 = 2\pi\sqrt{\frac{m}{k_2}}$$

$$t_{CD} = t_{DC} = \frac{60}{120} = 0.5\text{s}$$

$$T = 0.5 + \frac{2\pi}{2}\sqrt{\frac{0.2}{3.2}} + 0.5 + \frac{2\pi}{2}\sqrt{\frac{0.2}{1.8}}$$

$$T = 2.83\text{s}$$

38. (A → p; B → q, r; C → p; D → q, r)

A. Compare this with the standard equation of Simple Harmonic Motion (SHM).

$v = \omega\sqrt{A^2 - x^2}$

We can observe that the provided motion exhibits Simple Harmonic Motion (SHM) with $\omega = c_1$ and $A^2 = c_2$

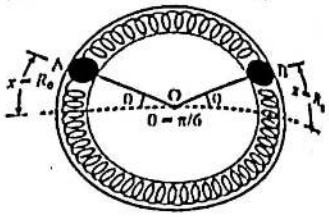
B. Equation shows that direction of motion remains unchanged and KE keeps decreasing.

C. Due to pseudo force the mean position will be changed.

D. Velocity is greater than escape velocity so it will go to infinity with decreasing speed.

39. Give, mass of each block A and B, $m = 0.1$ kg

Radius of circle, $R = 0.06$ m



Natural length of spring $l_0 = 0.06\ \pi = \pi l$ (Half circle) and spring constant, $k = 0.1$ kg/s. In the stretched position, the elongation in each spring is

$x = R\theta$.

Let us draw FBD of A.

The spring on the lower side is stretched by $2x$, while the spring on the upper side is compressed by $2x$. As a result, each spring will exert a force of $2kx$ on each block. Therefore, a restoring force, $F = 4kx$, will act on block A in the direction shown in the figure below.

The restoring torque of this force about the origin is

$\tau = -F \cdot R = -(4kx)R = -(4kR\theta)R$

or $\tau = -4kR^2 \cdot \theta$

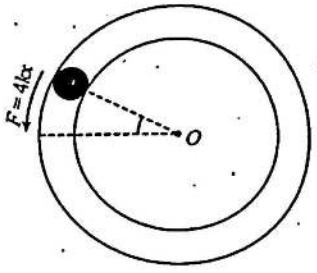
Since, $\tau \propto -\theta$, each ball executes angular SHM about origin O.

Eq. (*i*) can be modified as

$I\alpha = -4kR^2\theta$

or $(mR^2)\alpha = -4kR^2\theta$

or $\alpha = -\left(\frac{4k}{m}\right)\theta$



(a) Frequency of oscillation,

$$f = \frac{1}{2\pi}\sqrt{\frac{\text{acceleration}}{\text{displacement}}} = \frac{1}{2\pi}\sqrt{\frac{\alpha}{\theta}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{4k}{m}}$$

Substituting the values, we have

$$f = \frac{1}{2\pi}\sqrt{\frac{4 \times 0.1}{0.1}} = \frac{1}{\pi}\text{Hz}$$

(b) In the stretched position, the potential energy of the system is

@FAKE_CBSE_X_@RAJEEDUTT

$$PE = 2\left\{\frac{1}{2}k\right\}\{2x\}^2 = 4kx^2$$

And in the mean position, both blocks possess only kinetic energy. Hence

$$KE = 2\left\{\frac{1}{2}mv^2\right\} = mv^2$$

Applying energy conservation PE = KE

$$\therefore 4kx^2 = mv^2$$

$$\therefore v = 2x\sqrt{\frac{k}{m}} = 2R\theta\sqrt{\frac{k}{m}}$$

On putting the values v

$$= 2(0.06)(\pi/6)\sqrt{\frac{0.1}{0.1}}$$

or $v = 0.0628$ m/s

(c) Total energy of the system, E
= PE in stretched position
or = KE in mean position
$E = mv^2 = (0.1)(0.0628)^2$ J
or $E = 3.9 \times 10^{-4}$ J

40. Let x_1 be the extension when only m_2 is left. Then

$$kx_1 = m_2 g$$

$$x_1 = \frac{m_2 g}{k} \quad ...(i)$$

Angular frequency

$$\omega = \sqrt{k/m_2}$$

Likewise, let x_2 represent the extension when both masses were suspended.. Then-

$$kx_2 = (m_1 + m_2)g$$

$$x_2 = \frac{(m_1 + m_2)g}{k} \quad ...(ii)$$

Using both the equations, amplitude of the oscillations are

$$A = x_2 - x_1 = \frac{m_1 g}{k}$$

41. (c) Given Young's modulus,

$$Y = \frac{F}{A}\cdot\frac{I}{\Delta I}$$

Now elongation is given by

$$\Delta I = \frac{FI}{AY} = \frac{F}{\frac{AY}{I}} = \frac{F}{k}$$

Simply using the formula for ω,
Putting, ω = 140 rads^{-1} in above equation $\omega = \sqrt{\frac{K}{m}} = \sqrt{\frac{YA}{lm}}$

$$= \sqrt{\frac{(n\times10^9)(4.9\times10^{-7})}{1\times0.1}}$$

$$\therefore Y = \frac{\omega^2 ml}{A} = \frac{140\times140\times0.1\times1}{4.9\times10^{-7}}$$

$$= 4\times10^9$$

we get, $n = 4$.

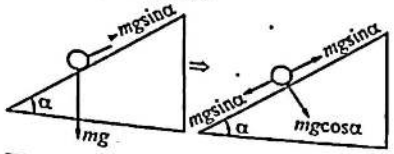
42. (a) $y = kt^2 \Rightarrow \frac{d^2y}{dt^2} = 2k$

or $a_y = 2$ m/s^2

$$T_1 = 2\pi\sqrt{\frac{l}{g}} \text{ and } T_2 = 2\pi\sqrt{\frac{l}{g + a_y}}$$

$$\therefore \frac{T_1^2}{T_2^2} = \frac{g + a_y}{g} = \frac{10+2}{10} = \frac{6}{5}$$

43. (a) The Free Body Diagram (FBD) of the pendulum bob, as observed from the accelerating frame of reference, is depicted as follows:



The net force acting on the pendulum bob is $F_{net} = mg\cos\alpha$

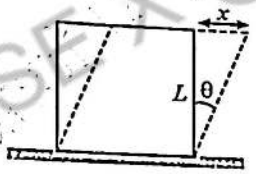
The net acceleration of the pendulum bob is $g_{eff} = g\cos\alpha$

$$T = 2\pi\sqrt{\frac{L}{g_{eff}}}$$

$$T = 2\pi\sqrt{\frac{L}{g\cos\alpha}}$$

44. (d) Modulus of rigidity is given by, $\eta = F/A\theta$

$A = L^2$ and $\theta = \frac{x}{L}$



Hence, restoring force is

$$F = -\eta A\theta = -\eta Lx$$

or acceleration, $\alpha = \frac{F}{M} = -\frac{\eta L}{M}x$

Because acceleration is proportional to $-x$, the oscillations exhibit simple harmonic motion (SHM) in nature, and the time period (T) is given by

$$T = 2\pi\sqrt{\left|\frac{\text{displacement}}{\text{acceleration}}\right|}$$

$$= 2\pi\sqrt{\left|\frac{x}{a}\right|} = 2\pi\sqrt{\frac{M}{\eta L}}$$

45. (c) The positively charged ring will attract the negatively charged particle held on the axis. The charge will travel to the other side of the ring as it reaches the centre due to the particle's inertia. Simultaneously, the ring's attractive force will prevent it from reaching infinity. As a result, it moves to a higher extreme and then returns. As a result, the charge begins to oscillate about the ring's centre.

The electric field on the axis of a ring at a distance x from the centre, distance

$$x < E = \frac{kQx}{R^3}$$

The net force on negatively charged particles would be qE, pushing them towards the ring's centre. As a result, we may write

$$F = -\frac{kQqx}{R^3}$$

Acceleration of the charge is

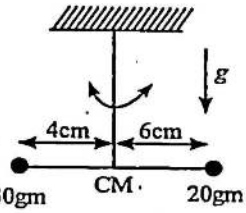
$$a = F/m = -\frac{kQqx}{mR^3} = -\omega^2 x$$

Time period of oscillations is

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{MR^3}{kQq}}$$

Substituting the values,
we get $T = 0.628$s

46. [10]



For torsional pendulum, $T = 2\pi\sqrt{\frac{I}{C}}$

or $\frac{2\pi}{\omega} = 2\pi\sqrt{\frac{I}{C}}$

$$\therefore \omega = \sqrt{\frac{C}{I}}$$

Moment of inertia of the system,
$I = (30)(4)^2 + (20)(6)^2$
$= 1200$ gm-cm^2
$= 1.2 \times 10^{-4}$ kg-m^2

$$\therefore \omega = \sqrt{\frac{1.2\times10^{-8}}{1.2\times10^{-4}}}$$

$\omega = (10^{-2}) = 10 \times 10^{-3}$ rad/s, $n = 10$

47. [1.6] For Case-1, $T = 2$s
Time period is given as

$$T = 2 = 2\pi\sqrt{\frac{M}{k}} \quad ...(i)$$

For Case-2, $T = 3$s

$$T_2 = 2\pi\sqrt{\frac{M+2}{k}} \quad ...(ii)$$

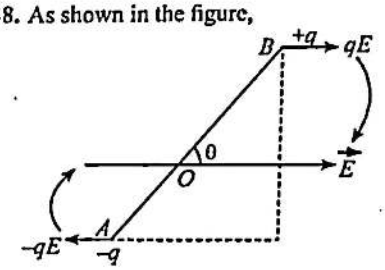
@FAKE_CBSE_X@RAJ_EDUNET

Taking the ratio of (*ii*) : (*i*) as

$$\frac{T_2}{T_1}=\sqrt{\frac{M+2}{M}}=\frac{3}{2}\Rightarrow\frac{9}{4}=\frac{M+2}{M}$$

$$\Rightarrow M=\frac{8}{5}=1.6\text{ kg}$$

48. As shown in the figure,



The torque that will act on the whole rod due to the forces acting on the charges will try to align it in the direction of the electric field.

The torque that will be acting is,

$\tau=-PE\sin\theta$ or $I\alpha=-PE\sin\theta$

$I=2M\left(\frac{L}{2}\right)^2=\frac{ML^2}{2}$ and $P=qL$

Since angle is small, $\sin\theta\approx\theta$

Putting the values in equation;

We get,

$$\left(\frac{ML^2}{2}\right)\alpha=-(qL)(E)\theta$$

$$\alpha=-\left(\frac{2qE}{ML}\right)\theta$$

We found that α is proportional to θ

As α is proportional to θ, motion of the rod is of simple harmonic in nature

Time period is given by

$$T=2\pi\sqrt{\left|\frac{\theta}{\alpha}\right|}=2\pi\sqrt{\frac{ML}{2qE}}$$

The desired time will be,

$$t=\frac{T}{4}=\frac{\pi}{2}\sqrt{\frac{ML}{2qE}}$$

49. At equilibrium $T=mg$ ...(*i*)

Now, $Y=\frac{T/A}{l/L}$

or, $T=\frac{YAl}{L}$

From (*i*) and (*ii*)

$$mg=\frac{YAl}{L}$$

Restoring force,

$F=-(T-mg)$

$$=-\left[\left(\frac{YA(l+x)}{L}\right)-\frac{YAl}{L}\right]=-\frac{YAx}{L}$$

We now that, $F=m\omega^2x$

So, $\frac{YAx}{L}=m\omega^2x$

or, $\omega=\sqrt{\frac{YA}{mL}}$

or, $\frac{2\pi}{T}=\sqrt{\frac{YA}{mL}}$

So, frequency $f=\frac{1}{T}=\frac{1}{2\pi}\left(\sqrt{\frac{YA}{mL}}\right)$

@FAKE_CBSE X @RAJ_EDUNET

16

Waves

Scan for Sol.

JEE-Main

Wave Equation

1. A plane progressive wave is given by $y = 2\cos 2\pi(330t - x)$ m. The frequency of the wave is : **[08 April, 2024 (Shift-II)]**
   (a) 165 Hz (b) 330 Hz
   (c) 660 Hz (d) 340 Hz

2. The equation of wave is given by $Y = 10^{-2}\sin 2\pi\left(160t - 0.5x + \frac{\pi}{4}\right)$
   Where x and Y are in m and t in s. The speed of the wave is _____ km h^{-1} **[11 April, 2023 (Shift-I)]**

3. A transverse harmonic wave on a string is given by $y(x, t) = 5\sin(6t + 0.003x)$
   where x and y are in cm and t in sec. The wave velocity is _____ ms^{-1}. **[10 April, 2023 (Shift-I)]**

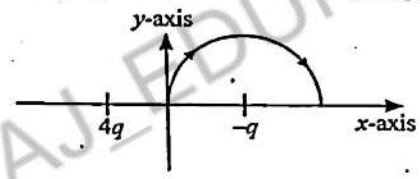
4. A longitudinal wave is represented by $x = 10\sin 2\pi\left(nt - \frac{x}{\lambda}\right)$ cm
   The maximum particle velocity will be four times the wave velocity if the determined value of wavelength is equal to: **[29 June, 2022 (Shift-I)]**
   (a) 2π (b) 5π (c) π (d) $\frac{5\pi}{2}$

5. Which of the following equations represents a traveling wave? **[24 Feb, 2021 (Shift-II)]**
   (a) $y = A\sin x\cos\omega t$ (b) $y = A\sin(15x - 2t)$
   (c) $y = Ae^{x}\cos(\omega t - \theta)$ (d) $y = Ae^{-x^2}(vt + \theta)$

6. Two waves are simultaneously passing through a string and their equations are: $y_1 = A_1\sin k(x - vt)$, $y_2 = A_2\sin k(x - vt + x_0)$. Given amplitudes $A_1 = 12$ mm and $A_2 = 5$ mm, $x_0 = 3.5$ cm and wave number $k = 6.28$ cm^{-1}. The amplitude of resulting wave will be _____ mm. **[26 Aug, 2021 (Shift-II)]**

7. For a transverse wave traveling along a straight line, the distance between two peaks (crests) is 5m, while the distance between one crest and one trough is 1.5m. The possible wavelengths (in m) of the waves are: **[4 Sep, 2020 (Shift-I)]**
   (a) 1, 3, 5, ... (b) $\frac{1}{1}, \frac{1}{3}, \frac{1}{5}, \frac{1}{4}\ldots$
   (c) $\frac{1}{2}, \frac{1}{4}, \frac{1}{6}, \frac{1}{4}\ldots$ (d) 1, 2, 3, ...

8. A two point charges $4q$ and $-q$ are fixed on the x-axis at $x = -d/2$ and $x = d/2$, respectively. If a third point charge 'q' is taken from the origin to $x = d$ along the semicircle as shown in the figure, the energy of the charge will **[4 Sep, 2020 (Shift-I)]**



   (a) Decrease by $\frac{q^2}{4\pi\varepsilon_0 d}$ (b) Decrease by $\frac{4q^2}{3\pi\varepsilon_0 d}$
   (c) Increase by $\frac{2q^2}{3\pi\varepsilon_0 d}$ (d) Increase by $\frac{3q^2}{4\pi\varepsilon_0 d}$

9. A travelling harmonic wave is represented by the equation $y(x, t) = 10^{-3}\sin(50t + 2x)$, where x and y are in meter and t is in seconds. Which of the following is a correct statement about the wave? **[12 Jan, 2019 (Shift-I)]**
   (a) The wave is propagating along the negative x-axis with speed 25 ms^{-1}.
   (b) The wave is propagating along the positive x-axis with speed 100 ms^{-1}.
   (c) The wave is propagating along the positive x-axis with speed 25 ms^{-1}.
   (d) The wave is propagating along the negative x-axis with speed 100 ms^{-1}.

Velocity of Wave, Energy and Power

10. A steel wire with mass per unit length 7.0×10^{-3} kg is under tension of 70 N. The speed of transverse waves in the wire will be: **[01 Feb, 2023 (Shift-I)]**
    (a) 200 π m/s (b) 100 m/s (c) 10 m/s (d) 50 m/s

11. A travelling wave is described by the equation $y(x,t) = [0.05\sin(8x - 4t)]m$
    The velocity of the wave is: [all the quantities are in SI unit] **[24 Jan, 2023 (Shift-I)]**
    (a) 4 ms^{-1} (b) 2 ms^{-1} (c) 0.5 ms^{-1} (d) 8 ms^{-1}

@FAKE_CBSE_X @RAJ_EDUNET

12. The fundamental frequency of vibration of a string stretched between two rigid support is 50 Hz. The mass of the string is 18 g and its linear mass density is 20 g/m. The speed of the transverse waves so produced in the string is _____ ms^{-1}. **[15 April 2023 (Shift-I)]**

13. In the wave equation

$$y = 0.5\sin\frac{2\pi}{\lambda}(400t - x)m$$

the velocity of the wave will be: **[28 July, 2022 (Shift-I)]**

(a) 200 m/s (b) $200\sqrt{2}$ m/s
(c) 400 m/s (d) $400\sqrt{2}$ m/s

14. A transverse wave is represented by $y = 2\sin(\omega t - kx)$cm. The value of wavelength (in cm) for which the wave velocity becomes equal to the maximum particle velocity will be: **[26 July, 2022 (Shift-II)]**

(a) 4π (b) 2π (c) π (b) 2

15. The mass per unit length of a uniform wire is 0.135 g/cm. A transverse wave of the form $y = -0.21\sin(x + 30t)$ is produced in it, where x is in meter and t is in second. Then, the expected value of tension in the wire is $x \times 10^{-2}$ N. Value of x is _____. (Round-off to the nearest integer) **[26 Feb, 2021 (Shift-I)]**

16. The amplitude of wave disturbance propagating in the positive x-direction is given by $y = \frac{1}{1+(x)^2}$ at $t = 0$ and $y = \frac{1}{1+(x-2)^2}$ at $t = 1$s, where x and y are in metres. The shape of wave does not change during the propagation. The velocity of the wave will be _____ m /s. **[20 July, 2021 (Shift-I)]**

17. A transverse wave travels on a taut steel wire with a velocity of v when tension in it is 2.06×10^4 N. When the tension is changed to T, the velocity changed to $v/2$. The value of T is close to: **[8 Jan, 2020 (Shift-II)]**

(a) 10.2×10^2 N (b) 30.5×10^4 N
(c) 5.15×10^3 N (d) 2.50×10^4 N

18. A string 2.0 m long and fixed at its end is driven by a 240 Hz vibrator. The string vibrates in its third harmonic mode. The speed of the wave and its fundamental frequency is: **[9 April, 2019 (Shift-II)]**

(a) 320 m/s, 120 Hz (b) 180 m/s, 80 Hz
(c) 180 m/s, 120 Hz (d) 320 m/s, 80 Hz

19. The pressure wave, $P = 0.01\sin[1000t - 3x]NM^{-2}$, corresponds to the sound produced by a vibrating blade on a day when atmospheric temperature is 0°C. On some other day when temperature is T, the speed of sound produced by the same blade and at the same frequency is found to be 336 ms^{-1}. Approximate value of T is: **[9 April, 2019 (Shift-I)]**

(a) 12°C (b) 11°C (c) 15°C (d) 4°C

20. Equation of travelling wave on a stretched string of linear density 5 g/m is $y = 0.03\sin(450t - 9x)$ where distance and time are measured in SI units. The tension in the string is: **[11 Jan, 2019 (Shift-I)]**

(a) 10 N (b) 7.5 N (c) 12.5 N (d) 5 N

21. A string of length 1 m and mass 5 g is fixed at both ends. The tension in the string is 8.0 N. The string is set into vibration using an external vibrator of frequency 100Hz. The separation between successive nodes on the string is close to: **[10 Jan, 2019 (Shift-I)]**

(a) 10.0 cm (b) 33.3 cm
(c) 16.6 cm (d) 20.0 cm

22. A light wave is incident normally on a glass slab of refractive index 1.5. If 4% of light gets reflected and the amplitude of the electric field of the incident light is 30 V/m, then the amplitude of the electric field for the wave propagating in the glass medium will be **[12 Jan, 2019 (Shift-I)]**

(a) 30 V/m (b) 10 V/m (c) 24 V/m (d) 6 V/m

Interference of Wave

23. Two waves of intensity ratio 1 : 9 cross each other at a point. The resultant intensities at the point, when (a) Waves are incoherent and (b) Waves are coherent is I_2 and differ in phase by 60°. If $\frac{I_1}{I_2} = \frac{14}{x}$ then x = _____. **[31 Jan, 2024 (Shift-I)]**

24. The equations of two waves are given by:

$y_1 = 5\sin2\pi(x - vt)$ cm

$y_2 = 3\sin2\pi(x - vt + 1.5)$ cm

These waves are simultaneously passing through a string. The amplitude of the resulting wave is: **[24 June, 2022 (Shift-I)]**

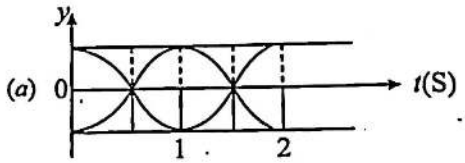
(a) 2 cm (b) 4 cm (c) 5.8cm (d) 8 cm

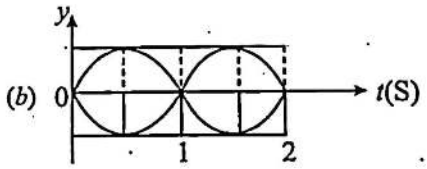
25. Two travelling waves of equal amplitudes and frequencies move in opposite directions along a string. They interfere to produce a stationary wave whose equation is given by $y = \left(10\cos\pi x\sin\frac{2\pi t}{T}\right)$ cm. The amplitude of the particle at $x = \frac{4}{3}$ cm will be _____cm. **[24 June, 2022 (Shift-II)]**

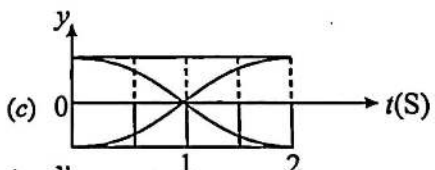
26. Three harmonic waves having equal frequency v and same intensity I_0, have phase angles 0, $\frac{\pi}{4}$ and $-\frac{\pi}{4}$ respectively. When they are superimposed the intensity of the resultant wave is close to **[9 Jan, 2020 (Shift-I)]**

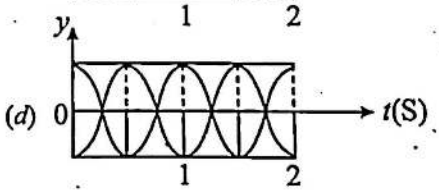
(a) $5.8\,I_0$ (b) $3\,I_0$ (c) I_0 (d) $0.2\,I_0$

27. The correct figure that shows, schematically, the wave pattern produced by superposition of two waves of frequencies 9 Hz and 11 Hz is: **[10 April, 2019 (Shift-II)]**

(a)


(b)


(c)


(d)


@BOOKS CODE X @RAJ_EDUNET

29. Two coherent sources produce waves of different intensities which interfere. After interference, the ratio of the maximum intensity to the minimum intensity is 16. The intensity of the waves are in the ratio
(a) 16 : 9 (b) 25 : 9 (c) 4 : 1 (d) 5 : 3
[9 Jan, 2019 (Shift-I)]

30. A heavy ball of mass M is suspended from the ceiling of car by a light string of mass m (m << M). When the car is at rest, the speed of transverse waves in the string is 60 ms^{-1}. When the car has acceleration a, the wave-speed increases to 60.5 ms^{-1}. The value of a, in terms of gravitational acceleration g is closest to:
[9 Jan, 2019 (Shift-I)]
(a) $\frac{g}{30}$ (b) $\frac{g}{5}$ (c) $\frac{g}{10}$ (d) $\frac{g}{20}$

Reflection of Waves and Standing Waves

30. In a closed organ pipe, the frequency of fundamental note is 30 Hz. A certain amount of water is now poured in the organ pipe so that the fundamental frequency is increased to 110 Hz. If the organ pipe has a cross-sectional area of 2 cm^2, the amount of water poured in the organ tube is _____ g. (Take speed of sound in air is 330 m/s) [30 Jan, 2024 (Shift-I)]

31. The equation of stationary wave is:

$$y = 2a \sin\left(\frac{2\pi nt}{\lambda}\right)\cos\left(\frac{2\pi x}{\lambda}\right)$$

Which of the following is NOT correct [04 April, 2024 (Shift-I)]
(a) The dimensions of nt is $[L]$
(b) The dimensions of n is $[LT^{-1}]$
(c) The dimensions of n/λ is $[T]$
(d) The dimensions of x is $[L]$

32. A sonometer wire of resonating length 90 cm has a fundamental frequency of 400 Hz when kept under some tension. The resonating length of the wire with fundamental frequency of 600 Hz under same tension _____ cm. [05 April, 2024 (Shift-II)]

33. A wire of density 8×10^3 kg/m^3 is stretched between two clamps 0.5m apart. The extension developed in the wire is 3.2×10^{-4}. If Y $= 8 \times 10^{10}$ N/m^2, the fundamental frequency of vibration in the wire will be _____ Hz. [11 April, 2023 (Shift-II)]

34. A guitar string of length 90 cm vibrates with a fundamental frequency of 120 Hz. The length of the string producing a fundamental frequency of 180 Hz will be _____ cm.
[08 April, 2023 (Shift-II)]

35. In an experiment with sonometer when a mass of 180 g is attached to the string, it vibrates with fundamental frequency of 30 Hz. When a mass m is attached, the string vibrates with fundamental frequency of 50 Hz. The value of m is _____ g. [13 April, 2023 (Shift-II)]

36. A string of length 1 m and mass 2×10^{-5} kg is under tension T. When the string vibrates, two successive harmonics are found to occur at frequencies 750 Hz and 1000 Hz. The value of tension T is _____ Newton. [JEE Adv, 2023]

37. A wire of length 30 cm, stretched between rigid supports, has it's n^{th} and $(n+1)^{th}$ harmonics at 400 Hz and 450 Hz, respectively. If tension in the string is 2700 N, it's linear mass density is _____ kg/m.
[27 July, 2022 (Shift-II)]

38. The percentage increase in the speed of transverse waves produced in a stretched string if the tension is increased by 4%, will be .....%.
[25 Feb, 2021 (Shift-II)]

39. A wire having a linear mass density 9.0×10^{-4} kg/m is stretched between two rigid supports with a tension of 900 N. The wire resonates at a frequency of 500 Hz. The next higher frequency at which the same wire resonates is 550 Hz. The length of the wire is _____ m. [31 Aug, 2021 (Shift-I)]

40. Two travelling waves produces a standing wave represented by equation, $y = 1.0$ mm cos (1.57 cm^{-1}) x sin (78.5s^{-1})t. The node closest to the origin in the region $x > 0$ will be at $x =$ _____ cm.
[26 Aug, 2021 (Shift-I)]

41. A uniform thin rope of length 12 m and mass 6 kg hangs vertically from a rigid support and a block of mass 2 kg is attached to its free end. A transverse short wave-train of wavelength 6 cm is produced at the lower end of the rope. What is the wavelength of the wave train (in cm) when it reaches the top of the rope?
(a) 6 (b) 12 (c) 3 (d) 9
[03 Sep, 2020 (Shift-I)]

42. Two identical strings X and Z made of same material have tension T_x and T_z in then if their fundamental frequencies are 450 Hz and 300 Hz, respectively, then the ratio T_x/T_z is:
[2 Sep, 2020 (Shift-I)]
(a) 1.25 (b) 2.25 (c) 1.5 (d) 0.44

43. A wire of length L and mass per unit length 6.0×10^{-3} kg m^{-1} is put under tension of 540 N. Two consecutive frequencies that it resonates at are 420 Hz and 490 Hz. Then L in meters is:
[9 Jan, 2020 (Shift-II)]
(a) 1.1 m (b) 5.1 m (c) 2.1 m (d) 8.1 m

44. A wire of density 9×10^{-3} kg cm^{-3} is stretched between two clamps 1 m apart. The resulting strain in the wire is 4.9×10^{-4}. The lowest frequency of the transverse vibrations in the wire (Young's modulus of wire $Y = 9 \times 10^{10}$ Nm^{-2}), (to the nearest integer) _____.
[2 Sep, 2020 (Shift-II)]

45. A wire of length $2L$, is made by joining two wires A and B of same lengths but different radii r and $2r$ and made of the same material. It is vibrating at a frequency such that the joint of the two wires forms a node. If the number of anti-nodes in wire A is p and that in B is q then the ratio $p : q$ is: [8 April, 2019 (Shift-I)]

(a) 4 : 9 (b) 3 : 5 (c) 1 : 4 (d) 1 : 2

46. 50 W/m^2 energy density of sunlight is normally incident on the surface of a solar panel. Some part of incident energy (25%) is reflected from the surface and the rest is absorbed. The force exerted on 1 m^2 surface area will be close to ($c = 3 \times 10^8$ m/s)
[9 April, 2019 (Shift-II)]
(a) 15×10^{-8} N (b) 35×10^{-8} N (c) 10×10^{-8} N (d) 20×10^{-8} N

47. A string is clamped at both the ends and it is vibrating in its 4th harmonic. The equation of the stationary wave is $Y = 0.3 \sin(0.157x)$ $\cos(200\pi t)$. The length of the string is: (All quantities are in SI units.)
[9 April, 2019 (Shift-I)]
(a) 20 m (b) 80 m (c) 60 m (d) 40 m

@TAKE_CBSE_X@BAD_BOYZ

Velocity of Sound Wave, Energy and Intensity

48. A point source is emitting sound waves of intensity 16×10^{-4} Wm^{-2} at the origin. The difference in intensity (magnitude only) at two points located at a distances of 2m and 4m from the origin respectively will be _____ $\times 10^{-4}$ Wm^{-2}.
[30 Jan, 2024 (Shift-II)]

49. The speed of sound in oxygen at S.T.P. will be approximately: (Given, R = 8.3 JK^{-1}, $\gamma = 1.4$) [31 Jan, 2024 (Shift-II)]
(a) 310 m/s (b) 333 m/s (c) 341 m/s (d) 325 m/s

50. Two open organ pipes of length 60 cm and 90 cm resonate at 6th and 5th harmonics respectively. The difference of frequencies for the given modes is _____ Hz.
(Velocity of sound in air = 333 m/s) [06 April, 2024 (Shift-II)]

51. The ratio of speed of sound in hydrogen gas to the speed of sound in oxygen gas at the same temperature.is:
[06 April, 2023 (Shift-II)]
(a) 4 : 1 (b) 1 : 2 (c) 1 : 4 (d) 1 : 1

Vibration in Air Column and Beats

52. A closed organ pipe 150 cm long gives 7 beats per second with an open organ pipe of length 350 cm, both vibrating in fundamental mode. The velocity of sound is _____ m/s.
[27 Jan, 2024 (Shift-II)]

53. The fundamental frequency of a closed organ pipe is equal to the first overtone frequency of an open organ pipe. If length of the open pipe is 60 cm, the length of the closed pipe will be:
[31 Jan, 2024 (Shift-I)]
(a) 60 cm (b) 45 cm (c) 30 cm (d) 15 cm

54. A tuning fork resonates with a sonometer wire of length 1 m stretched with a tension of 6 N. When the tension in the wire is changed to 54 N, the same tuning fork produces 12 beats per second with it. The frequency of the tuning fork is _____ Hz.
[1 Feb, 2024 (Shift-I)]

55. A closed and an open organ pipe have same lengths. If the ratio of frequencies of their seventh overtones is $\left(\frac{a-1}{a}\right)$ then the value of a is _____.
[08 April, 2024 (Shift-I)]

56. For a certain organ pipe, the first three resonance frequencies are in the ratio of 1 : 3 : 5 respectively. If the frequency of fifth harmonic is 405 Hz and the speed of sound in air is 324 ms^{-1} the length of the organ pipe is _____ m. [12 April, 2023 (Shift-I)]

57. An organ pipe 40 cm long is open at both ends. The speed of sound in air is 360 ms^{-1}. The frequency of the second harmonic is _____ Hz. [08 April, 2023 (Shift-I)]

58. In an experiment to determine the velocity of sound in air at room temperature using a resonance tube, the first resonance is observed when the air column has a length of 20.0 cm for a tuning fork of frequency 400 Hz is used. The velocity of the sound at room temperature is 336 ms^{-1}. The third resonance is observed when the air column has a length of _____cm. [29 June, 2022 (Shift-II)]

59. The first overtone frequency of an open organ pipe is equal to the fundamental frequency of a closed organ pipe. If the length of the closed organ pipe is 20 cm. The length of the open organ pipe is _____ cm. [25 June, 2022 (Shift-I)]

60. A tunning fork of frequency 340 Hz resonates in the fundamental mode with a air column of length 125 cm in a cylindrical tube closed at one end. When water is slowly poured in it, the minimum height of water required for observing resonance once again is _____ cm. (Velocity of sound in air is 340 ms^{-1}) [28 June, 2022 (Shift-II)]

61. A tuning fork A of unknown frequency produces 5 beats/s with a fork of known frequency 340 Hz. When fork A is filed, the beat frequency decreases to 2 beats/s. What is the frequency of fork A?
[26 Feb, 2021 (Shift-II)]
(a) 345 Hz (b) 338 Hz (c) 342 Hz (d) 335 Hz

62. A closed organ pipe of length L and an open organ pipe contain gases of densities ρ_1 and ρ_2 respectively.
The compressibility of gases are equal in both the pipes. Both the pipes are vibrating in their first overtone with same frequency. The length of the open pipe is $\frac{x}{3}L\sqrt{\frac{\rho_1}{\rho_2}}$ where x is (Round off to the Nearest Integer) [16 March, 2021 (Shift-II)]

63. A tuning fork is vibrating at 250 Hz. The length of the shortest closed organ pipe that will resonate with the tuning fork will be _____ cm. (Take speed of sound in air as 340 ms^{-1}) [27 Aug, 2021 (Shift-II)]

64. In a resonance tube experiment when the tube is filled with water up to a height of 17.0 cm from bottom, it resonates with a given tuning fork. When the water level is raised the next resonance with the same tuning fork occurs at a height of 24.5 cm. If the velocity of sound in air is 330 m/s, the tuning fork frequency is
[05 Sep, 2020 (Shift-I)]
(a) 2200 Hz (b) 3300 Hz (c) 1100 Hz (d) 550 Hz

65. A one metre long (both ends open) organ pipe is kept in a gas that has double the density of air at STP. Assuming the speed of sound in air at STP is 300 m/s, the frequency difference between the fundamental and second harmonic of this pipe is _____Hz.
[8 Jan, 2020 (Shift-I)]

66. A stationary tuning fork is in resonance with an air column in a pipe. If the tuning fork is moved with a speed of 2 ms^{-1} in front of the open end of the pipe and parallel to it, the length of the pipe should be changed for the resonance to occur with the moving tuning fork. If the speed of sound in air is 320 ms^{-1}, the smallest value of the percentage change required in the length of the pipe is_____. [JEE Adv, 2019]

67. A tuning fork of frequency 480 Hz is used in an experiment for measuring speed of sound (V) in air by resonance tube method. Resonance is observed to occur at two successive lengths of the air column, $\ell_1 = 30$ cm and $\ell_2 = 70$ cm. Then V is equal to:
[12 April, 2019 (Shift-II)]
(a) 332 ms^{-1} (b) 338 ms^{-1} (c) 384 ms^{-1} (d) 397 ms^{-1}

68. A closed organ pipe has a fundamental frequency of 1.5 kHz. The number of overtones that can be distinctly heard by a person with this organ pipe will be: (Assume that the highest frequency a person can hear is 20,000 Hz)
[10 Jan, 2019 (Shift-II)]
(a) 6 (b) 4 (c) 7 (d) 5

@FAKE_BSE_X@RAJDUNE

Wave Equation

Multiple Correct

1. $y(x,t)=\frac{0.8}{[(4x+5t)^2+5]}$ represents a moving pulse where x and y are in meter and t is in second. Then, **(IIT-JEE 1999)**
   (a) Pulse is moving in positive x-direction
   (b) In 2s it will travel a distance of 2.5 m
   (c) Its maximum displacement is 0.16 m
   (d) It is a symmetric pulse

2. In a wave motion $y = a\sin(kx-\omega t)$, y can represent **(IIT-JEE 1999)**
   (a) Electric field (b) Magnetic field
   (c) Displacement (d) Pressure

3. As a wave propagates **(IIT-JEE 1999)**
   (a) The wave intensity remains constant for a plane wave
   (b) The wave intensity decreases as the inverse of the distance from the source for a spherical wave
   (c) The wave intensity decreases as the inverse square of the distance from the source for a spherical wave
   (d) Total intensity of the spherical wave over the spherical surface centered at the source remains constant at all times

Numerical Types/Integer Types

4. When two progressive waves $y_1 = 4\sin(2x-6t)$ and $y_2 = 3\sin(2x-6t-\pi/2)$ are superimposed, the amplitude of the resultant wave is **(IIT-JEE 2010)**

Fill in the Blanks

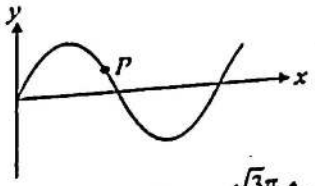
5. A plane progressive wave of frequency 25 Hz, amplitude 2.5×10^{-5} m and initial phase zero propagates along the negative x - direction with a velocity of 300 m/s. At any instant, the phase difference between the oscillations at two points 6 m apart along the line of propagation is ____ and the corresponding amplitude difference is ____ m. **(IIT-JEE 1997)**

6. A travelling wave has the frequency ν and the particle displacement amplitude A. For the wave the particle velocity amplitude is _____ and the particle acceleration amplitude is _____. **(IIT-JEE 1983)**

Velocity of Wave, Energy and Power

Single Correct

7. A transverse sinusoidal wave moves along a string in the positive x-direction at a speed of 10 cm/s. The wavelength of the wave is 0.5 m and its amplitude is 10 cm. At a particular time t, the snap-shot of the wave is shown in figure. The velocity of point P when its displacement is 5 cm is **(IIT-JEE 2008)**



(a) $\frac{\sqrt{3}\pi}{50}\hat{j}$ m/s (b) $-\frac{\sqrt{3}\pi}{50}\hat{j}$ m/s

(c) $\frac{\sqrt{3}\pi}{50}\hat{i}$ m/s (d) $-\frac{\sqrt{3}\pi}{50}\hat{i}$ m/s

8. The ends of a stretched wire of length L are fixed at $x = 0$ and $x = L$. In one experiment the displacement of the wire is $y_1 = A\sin\left(\frac{\pi x}{L}\right)\sin\omega t$ and energy is E_1 and in other experiment its displacement is $y_2 = A\sin\left(\frac{2\pi x}{L}\right)\sin2\omega t$ and energy is E_2. Then **(IIT-JEE 2001)**

(a) $E_2 = E_1$ (b) $E_2 = 2E_1$ (c) $E_2 = 4E_1$ (d) $E_2 = 16E_1$

9. A traveling wave in a stretched string is described by the equation $y = A\sin(kx - \omega t)$ The maximum particle velocity is **(IIT-JEE 1997)**

(a) $A\omega$ (b) ω/k (c) $d\omega/dk$ (d) x/ω

10. The extension in a string, obeying Hooke's law, is x. The speed of transverse wave in the stretched string is v. If the extension in the string is increased to $1.5x$, the speed of transverse wave will be **(IIT-JEE 1996)**

(a) 1.22 v (b) 0.61 v (c) 1.50 v (d) 0.75 v

11. A transverse wave is described by the equation $y = y_0\sin2\pi\left(ft-\frac{x}{\lambda}\right)$ The maximum particle velocity is equal to four times the wave velocity if **(IIT-JEE 1984)**

(a) $\lambda = \pi y_0/4$ (b) $\lambda = \pi y_0/2$ (c) $\lambda = \pi y_0$ (d) $\lambda = 2\pi y_0$

Multiple Correct

12. A transverse sinusoidal wave of amplitude a, wavelength λ and frequency f is traveling on a stretched string. The maximum speed of any point on the string is $v/10$, where v is the speed of propagation of the wave. If $a = 10^{-3}$ m and $v = 10$ m/s, then λ and f are given by **(IIT-JEE 1998)**

(a) $\lambda = 2\pi\times10^{-2}$ m (b) $\lambda = 10^{-3}$ m

(c) $f = \frac{10^3}{2\pi}$ Hz (d) $f = 10^4$ Hz

13. A wave is represented by the equation; $y = A\sin(10\pi x + 15\pi t + \pi/3)$ where, x is in metre and t is in second. The expression represents **(IIT-JEE 1990)**

(a) a wave travelling in the positive x-direction with a velocity 1.5 m/s
(b) a wave travelling in the negative x-direction with a velocity 1.5 m/s
(c) a wave travelling in the negative x-direction with a wavelength 0.2 m
(d) a wave travelling in the positive x-direction with a wavelength 0.2 m

@PACE CBSE X @PACE EDUNET

14. A wave equation which gives the displacement along the y-direction is given by: $y = 10^{-4} \sin(60t + 2x)$ where, x and y are in meter and t is time in second. This represents a wave (IIT-JEE 1981)

(a) Travelling with a velocity of 30 m/s in the negative x - direction

(b) Of wavelength (π) m

(c) Of frequency $\left(\frac{30}{\pi}\right)$ Hz

(d) Of amplitude 10^{-4} m

Numerical Types/Integer Typos

15. Four harmonic waves of equal frequencies and equal intensities I_0 have phase angles $0, \frac{\pi}{3}, \frac{2\pi}{3}$ and π. When they are superposed, the intensity of the resulting wave is nI_0. The value of n is (JEE Adv. 2015)

16. The amplitude of a wave disturbance travelling in the positive x-direction is given by $y = \frac{1}{(1+x)^2}$ at time $t = 0$ and by. $y = \frac{1}{[1+(x-1)^2]}$ at $t = 2$s, where x and y are in metre.

The shape of the wave disturbance does not change during the propagation. The velocity of the wave is m/s. (IIT-JEE 1990)

17. A uniform rope of length 12 m and mass 6 kg hangs vertically from a rigid support. A block of mass 2 kg is attached to the free end of the rope. A transverse pulse of wavelength 0.06 m is produced at the lower end of the rope. What is the wavelength of the pulse when it reaches the top of the rope? (IIT-JEE 1984)

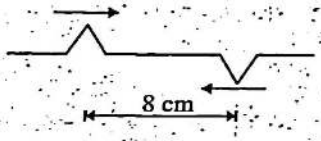
Subjective

18. A harmonically moving transverse wave on a string has a maximum particle velocity and acceleration of 3 m/s and 90 m/s² respectively. Velocity of the wave is 20 m/s. Find the waveform. (IIT-JEE 2005)

Interference of Wave

Single Correct

19. Two pulses in a stretched string, whose centers are initially 8 cm apart, are moving towards each other as shown in the figure. The speed of each pulse is 2 cm/s. After 2 s the total energy of the pulses will be (IIT-JEE 2001)



(a) Zero

(b) Purely kinetic

(c) Purely potential

(d) Partly kinetic and partly potential

20. A string of length 0.4 m and mass 10^{-2} kg is tightly clamped at its ends. The tension in the string is 1.6 N. Identical wave pulses are produced at one end at equal intervals of time Δt. The minimum value of Δt, which allows constructive interference between successive pulses, is (IIT-JEE 1998)

(a) 0.05 s (b) 0.10 s (c) 0.20 s (d) 0.40 s

21. The displacement y of a particle executing periodic motion is given by $y = 4\cos^2\left(\frac{1}{2}t\right)\sin(1000t)$

This expression may be considered to be a result of the superposition of _____ independent harmonic motions. (IIT-JEE 1992)

(a) Two (b) Three (c) Four (d) Five

Subjective

22. Two radio stations broadcast their programmes at the same amplitude A and at slightly different frequencies ω_1 and ω_2 respectively, where $\omega_1 - \omega_2 = 10^3$ Hz. A detector receives the signals from the two stations simultaneously. It can only detect signals of intensity $\geq 2A^2$. (IIT-JEE 1993)

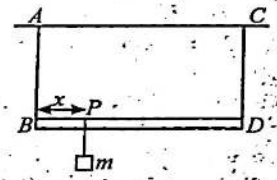
(a) Find the time interval between successive maxima of the intensity of the signal received by the detector.

(b) Find the time for which the detector remains idle in each cycle of the intensity of the signal.

Reflection of Waves and Standing Waves

Single Correct

23. A massless rod BD is suspended by two identical massless strings AB and CD of equal lengths. A block of mass m is suspended from point P such that BP is equal to x. If the fundamental frequency of the left wire is twice the fundamental frequency of right wire, then the value of x is (IIT-JEE 2006)



(a) $l/5$ (b) $l/4$ (c) $4l/5$ (d) $3l/4$

24. A sonometer wire resonates with a given tuning fork forming standing waves with five antinodes between the two bridges when a mass of 9 kg is suspended from the wire. When this mass is replaced by mass M, the wire resonates with the same tuning fork forming three antinodes for the same positions of the bridges. The value of M is (IIT-JEE 2002)

(a) 25 kg (b) 5 kg (c) 12.5 kg (d) 1/25 kg

25. An object of specific gravity ρ is hung from a thin steel wire. The fundamental frequency for transverse standing waves in the wire is 300 Hz. The object is immersed in water, so that one half of its volume is submerged. The new fundamental frequency (in Hz) is (IIT-JEE 1995)

(a) $300\left(\frac{2\rho-1}{2\rho}\right)^{1/2}$ (b) $300\left(\frac{2\rho}{2\rho-1}\right)^{1/2}$

(c) $300\left(\frac{2\rho}{2\rho-1}\right)$ (d) $300\left(\frac{2\rho-1}{2\rho}\right)$

@FAKE CBSE X@PU EDUNET

26. A wave represented by the equation $y = a\cos(kx - \omega t)$ is superimposed with another wave to form a stationary wave such that point $x = 0$ is a node. The equation for the other wave is (IIT-JEE 1988)

(a) $a\sin(kx + \omega t)$ (b) $-a\cos(kx - \omega t)$

(c) $-a\cos(kx + \omega t)$ (d) $-a\sin(kx - \omega t)$

Multiple Correct

27. One end of a taut string of length 3 m along the $X-$ axis is fixed at $x = 0$. The speed of the waves in the string is 100 ms^{-1}. The other end of the string is vibrating in the $y-$ direction so that stationary waves are set up in the string. The possible waveform(s) of these stationary wave is (are) C-7.4 W-81.63 UA-10.97 (JEE Adv. 2014)

(a) $y(t) = A\sin\frac{\pi x}{6}\cos\frac{50\pi t}{3}3$ (b) $y(t) = A\sin\frac{\pi x}{3}\cos\frac{100\pi t}{3}$

(c) $y(t) = A\sin\frac{5\pi x}{6}\cos\frac{250\pi t}{3}$ (d) $y(t) = A\sin\frac{5\pi x}{2}\cos 250\pi t$

28. Standing waves can be produced (IIT-JEE 1999)

(a) On a string clamped at both ends

(b) On a string clamped at one end and free at the other

(c) When incident wave gets reflected from a wall

(d) When two identical waves with a phase difference of π are moving in the same direction

29. The (x, y) coordinates of the corners of a square plate are $(0, 0)$, $(L, 0,)$, (L, L), and $(0, L)$. The edges of the plate are clamped and transverse standing waves are set-up in it. If $u(x, y)$ denotes the displacement of the plate at the point (x, y) at some instant of time, the possible expression (s) for u is (are) (a = positive constant) (IIT-JEE 1998)

(a) $a\cos(\pi x/2L)\cos(\pi y/2L)$ (b) $a\sin(\pi x/L)\sin(\pi y/L)$

(c) $a\sin(\pi x/L)\sin(2\pi y/L)$ (d) $a\cos(2\pi x/L)\sin(\pi y/L)$

Numerical Types/Integer Types

30. A string of length 1 m and mass 2×10^{-5} kg is under tension T. When the string vibrates, two successive harmonics are found to occur at frequencies 750 Hz and 1000 Hz. The value of tension T is _____ Newton. C-22.64 W-54.39 UA-22.97 (JEE Adv. 2023)

31. A steel wire of length 1 m, mass 0.1 kg and uniform cross-sectional area 10^{-6} m^2 is rigidly fixed at both ends. The temperature of the wire is lowered by 20°C. If transverse waves are set-up by plucking the string in the middle, calculate the frequency of the fundamental mode of vibration. (IIT-JEE 1984)

Given : $Y_{steel} = 2 \times 10^{11}$ N/m^2, $\alpha_{steel} = 1.21 \times 10^{-5}$/°C.

Fill in the Blanks

32. Sound waves of frequency 660 Hz fall normally on a perfectly reflecting wall. The shortest distance from the wall at which the air particles have maximum amplitude of vibration is ____ m. (Speed of sound = 330 m/s). (IIT-JEE 1984)

Subjective

33. A string of mass per unit length μ is clamped at both ends such that one end of the string is at $x = 0$ and the other is at $x = l$. When string vibrates in fundamental mode amplitude of the midpoint O of the string is a, and tension in the string is T. Find the total oscillation energy stored in the string. (IIT-JEE 2003)

34. A long wire PQR is made by joining two wires PQ and QR of equal radii. PQ has length 4.8 m and mass 0.06 kg. QR has length 2.56 m and mass 0.2 kg. The wire PQR is under a tension of 80 N. A sinusoidal wave pulse of amplitude 3.5 cm is sent along the wire PQ from the end P. No power is dissipated during the propagation of the wave pulse. Calculate: (IIT-JEE 1999)

(a) the time taken by the wave pulse to reach the other end R and

(b) the amplitude of the reflected and transmitted wave pulse after the incident wave pulse crosses the joint Q.

35. The displacement of the medium in a sound wave is given by the equation $y_1 = A\cos(ax + bt)$ where A, a and b are positive constants. The wave is reflected by an obstacle situated $ax = 0$. The intensity of the reflected wave is 0.64 times that of the incident wave. (IIT-JEE 1991)

(a) What are the wavelength and frequency of incident wave ?

(b) Write the equation for the reflected wave.

(c) In the resultant wave formed after reflection, find the maximum and minimum values of the particle speeds in the medium.

(d) Express the resultant wave as a superposition of a standing wave and a travelling wave. What are the positions of the antinodes of the standing wave? What is the direction of propagation of travelling wave ?

36. The following equations represent transverse waves;
$z_1 = A\cos(kx - \omega t)$; $z_2 = A\cos(kx + \omega t)$;
$z_3 = A\cos(ky - \omega t)$
Identify the combination (s) of the waves which will produce (IIT-JEE 1987)

(a) Standing wave

(b) A wave travelling in the direction making an angle of 45 degrees with the positive X and positive Y-axes. In each case, find the position at which the resultant intensity is always zero.

Velocity of Sound Wave, Energy and Intensity

Single Correct

37. Two plane harmonic sound waves are expressed by the equations.
$y_1(x, t) = A\cos(0.5\pi x - 100\pi t)$
$y_2(x, t) = A\cos(0.46\pi x - 92\pi t)$
(All parameters are in MKS)
What is the speed of the sound? (IIT-JEE 2006)

(a) 200 m/s (b) 180 m/s

(c) 192 m/s (d) 96 m/s

38. Two monoatomic ideal gases 1 and 2 of molecular masses m_1 and m_2 respectively are enclosed in separate containers kept at the same temperature. The ratio of the speed of sound in gas 1 to the gas 2 is given by (IIT-JEE 2000)

(a) $\sqrt{\frac{m_1}{m_2}}$ (b) $\sqrt{\frac{m_2}{m_1}}$ (c) $\frac{m_1}{m_2}$ (d) $\frac{m_2}{m_1}$

39. The ratio of the speed of sound in nitrogen gas to that in helium gas, at 300 K is (IIT-JEE 1999)

(a) $\sqrt{(2/7)}$ (b) $\sqrt{(1/7)}$ (c) $(\sqrt{3})/5$ (d) $(\sqrt{6})/5$

@FIITJEE_BSK@RALEDUNET

Multiple Correct

40. In an experiment to measure the speed of sound by a resonating air column, a tuning fork of frequency 500 Hz is used. The length of the air column is varied by changing the level of water in the resonance tube. Two successive resonances are heard at air columns of length 50.7 cm and 83.9 cm. Which of the following statements is (are) true? **C-20.66 W-21.12 UA-43.88 PC-14.35 (JEE Adv. 2018)**
   (a) The speed of sound determined from this experiment is 332 ms^{-1}
   (b) The end correction in this experiment is 0.9 cm
   (c) The wavelength of the sound wave is 66.4 cm
   (d) The resonance at 50.7 cm corresponds to the fundamental harmonic

Fill in the Blanks

41. A point source emits sound equally in all directions in a non-absorbing medium. Two points P and Q are at a distance 9 m and 25 m respectively from the source. The ratio of amplitudes of the waves at P and Q is ..... **(IIT-JEE 1989)**

True/False

42. The ratio of the velocity of sound in hydrogen gas $\left(\gamma=\frac{7}{5}\right)$ to that in helium gas $\left(\gamma=\frac{5}{3}\right)$ at the same temperature is $\sqrt{21/5}$. **(IIT-JEE 1983)**

Interference and Reflection of Sound Wave

Match the Column

Direction: *Q.43 and Q.44 by appropriately matching the lists based on the information given in the paragraph.*

A musical instrument is made using four different metal strings, 1, 2, 3 and 4 with mass per unit length μ, 2μ, 3μ and 4μ respectively. The instrument is played by vibrating the strings by varying. The free length in between the range L_0 and $2L_0$. It is found that in siring-1 (μ) at free length L_0 and tension T_0 the fundamental mode frequency is f_0.

List-I gives the above four strings while List-II lists the magnitude of some quantity.

List-I	List-II
(I) String-1 (μ)	(P) 1
(II) String-2 (2μ)	(Q) $\frac{1}{2}$
(III) String-3 (3μ)	(R) $\frac{1}{\sqrt{2}}$
(IV) String-4 (4μ)	(S) $\frac{1}{\sqrt{3}}$
	(T) $\frac{3}{16}$
	(U) $\frac{1}{16}$

43. If the tension in each string is T_0, the correct match for the highest fundamental frequency in f_0 units will be.
C-37.82 W-22.48 UA-39.7 (JEE Adv. 2015)
   (a) I→P, II→Q, III→T, IV→S (b) I→P, II→R, III→S, IV→Q
   (c) I→Q, II→S, III→R, IV→P (d) I→Q, II→P, III→R, IV→T

44. The length of the strings 1, 2, 3 and 4 are kept fixed at L_0, $\frac{3L_0}{2}$, $\frac{5L_0}{4}$ and $\frac{7L_0}{4}$ respectively.
Strings 1, 2, 3 and 4 are vibrated at their 1st, 3rd, 5th and 14th harmonics, respectively such that all the strings have same frequency. The correct match for the tension in the four strings in the units of T_0 will be.
C-40.14 W-20.2 UA-39.66 (JEE Adv. 2015)
   (a) I→P, II→R, III→T, IV→U
   (b) I→P, II→Q, III→T, IV→U
   (c) I→P, II→Q, III→R, IV→T
   (d) I→T, II→Q, III→R, IV→U

True/False

45. A plane wave of sound traveling in air is incident upon a plane water surface. The angle of incidence is 60°. Assuming Snell's law to be valid for sound waves, it follows that the sound wave will be refracted into water away from the normal. **(JEE Adv. 2020)**

Vibration in Air Column, Organ Pipe and Beats

Single Correct

46. A student is performing an experiment using a resonance column and a tuning fork of frequency 244 s^{-1}. He is told that the air in the tube has been replaced by another gas (assume that the column remains filled with the gas). If the minimum height at which resonance occurs is (0.350 ± 0.005) m, the gas in the tube is
C-4.73 W-76.06 UA-19.21 (JEE Adv. 2016)
(Useful information : $\sqrt{167RT}=640\,J^{1/2}$ $mole^{-1/2}$; $\sqrt{140RT}=590\,J^{1/2}\,mole^{-1/2}$. The molar masses M in grams are given in the options. Take the value of $\sqrt{10/M}$ for each gas as given there.)
   (a) Neon $\left(M=20;\sqrt{10/20}=7/10\right)$
   (b) Nitrogen $\left(M=28;\sqrt{10/28}=3/5\right)$
   (c) Oxygen $\left(M=32;\sqrt{10/32}=9/16\right)$
   (d) Argon $\left(M=36;\sqrt{10/36}=17/32\right)$

47. A student is performing an experiment on the resonance column. The diameter of the column tube is 4 cm. The frequency of the tuning fork is 512 Hz. The air temperature is 38°C in which the speed of sound is 336 m/s. The zero of the meter scale coincides with the top end of the resonance column tube. When the first resonance occurs, the reading of the water level in the column is
C-11.89 W-28.55 UA-59.55 (JEE Adv. 2017)
(a) 14.0 cm (b) 15.2 cm (c) 16.4 cm (d) 17.6 cm

@FACE_FREE_X@RALEDUSET

48. A hollow pipe of length 0.8 m is closed at one end. At its open end a 0.5 m long uniform string is vibrating in its second harmonic and it resonates with the fundamental frequency of the pipe. If the tension in the wire is 50 N and the speed of sound is 320 ms^{-1}, the mass of the string is (IIT-JEE 2010)
(a) 5 g (b) 10 g (c) 20 g (d) 40 g

49. A vibrating string of certain length l under a tension T resonates with a mode corresponding to the first overtone (third harmonic) of an air column of length 75 cm inside a tube closed at one end. The string also generates 4 beats/s when excited along with a tuning fork of frequency n. Now when the tension of the string is slightly increased the number of beats reduces to 2 per second. Assuming the velocity of sound in air to be 340 m/s, the frequency n of the tuning fork in Hz is (IIT-JEE 2008)
(a) 344 (b) 336 (c) 117.3 (d) 109.3

50. Two plane harmonic sound waves are expressed by the equations.
$y_1(x, t) = A\cos(0.5\pi x - 100\pi t)$
$y_2(x, t) = A\cos(0.46\pi x - 92\pi t)$
(All parameters are in MKS)
How many times does an observer hear maximum intensity in one second? (IIT-JEE 2006)
(a) 4 (b) 10 (c) 6 (d) 8

51. A tuning fork of 512 Hz is used to produce resonance in a resonance tube experiment. The level of water at first resonance is 30.7 cm and at second resonance is 63.2 cm. The error in calculating velocity of sound is (IIT-JEE 2005)
(a) 204.1 cm/s (b) 110 cm/s
(c) 58 cm/s (d) 280 cm/s

52. An open pipe is in resonance in 2nd harmonic with frequency f_1. Now one end of the tube is closed and frequency is increased to f_2 such that the resonance again occurs in nth harmonic. Choose the correct option. (IIT-JEE 2005)
(a) $n = 3, f_2 = (3/4)f_1$ (b) $n = 3, f_2 = (5/4)f_1$
(c) $n = 5, f_2 = (5/4)f_1$ (d) $n = 5, f_2 = (3/4)f_1$

53. A closed organ pipe of length L and an open organ pipe contain gases of densities ρ_1 and ρ_2 respectively. The compressibility of gases are equal in both the pipes. Both the pipes are vibrating in their first overtone with the same frequency. The length of the open organ pipe is (IIT-JEE 2004)
(a) $\frac{L}{3}$ (b) $\frac{4L}{3}$ (c) $\frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$ (d) $\frac{4L}{3}\sqrt{\frac{\rho_2}{\rho_1}}$

54. In the experiment for the determination of the speed of sound in air using the resonance column method, the length of the air column that resonates in the fundamental mode, with a tuning fork is 0.1 m. When this length is changed to 0.35 m, the same tuning fork resonates with the first overtone. Calculate the end correction. (IIT-JEE 2003)
(a) 0.012 m (b) 0.025 m (c) 0.05 m (d) 0.024 m

55. Two vibrating strings of the same material but of lengths L and $2L$ have radii $2r$ and r respectively. They are stretched under the same tension. Both the strings vibrate in their fundamental modes. The one of length L with frequency v_1 and the other with frequency v_2. The ratio v_1/v_2 is given by (IIT-JEE 2000)
(a) 2 (b) 4 (c) 8 (d) 1

56. An open pipe is suddenly closed at one end with the result that the frequency of third harmonic of the closed pipe is found to be higher by 100 Hz then the fundamental frequency of the open pipe. The fundamental frequency of the open pipe is (IIT-JEE 1996)
(a) 200 Hz (b) 300 Hz (c) 240 Hz (d) 480 Hz

57. An organ pipe P_1 closed at one end vibrating in its first harmonic and another pipe P_2 open at both ends vibrating in its third harmonic are in resonance with a given tuning fork. The ratio of the length of P_1 and P_2 is (IIT-JEE 1988)
(a) 8/3 (b) 3/8 (c) 1/6 (d) 1/3

58. A tube, closed at one end and containing air, produces, when excited, the fundamental note of frequency 512 Hz. If the tube is opened at both ends the fundamental frequency that can be excited is (in Hz) (IIT-JEE 1986)
(a) 1024 (b) 512 (c) 256 (d) 1/3

59. A cylindrical tube, open at both ends, has a fundamental frequency f in air. The tube is dipped vertically in water so that half of its length is in water. The fundamental frequency of the air column is now (IIT-JEE 1981)
(a) $f/2$ (b) $3f/4$ (c) f (d) $2f$

Multiple Correct

60. A student performed an experiment to measure the speed of sound in air using the resonance air-column method. Two resonances in the air-column were obtained by lowering the water level. The resonance with the shorter air-column is the first resonance and that with the longer air column is the second resonance. Then, (IIT-JEE 2009)
(a) The intensity of the sound heard at the first resonance was more than that at the second resonance
(b) The prongs of the tuning fork were kept in a horizontal plane above the resonance tube
(c) The amplitude of vibration of the ends of the prongs is typically around 1 cm
(d) The length of the air-column at the first resonance was somewhat shorter than $1/4^{th}$ of the wavelength of the sound in air

61. A wave disturbance in a medium is described by $y(x, t) = 0.02 \cos\left(50\pi t + \frac{\pi}{2}\right)\cos(10\pi x)$, where x and y are in meter and t is in second. (IIT-JEE 1995)
(a) A node occurs at $x = 0.15$ m
(b) An antinode occurs at $x = 0.3$ m
(c) The speed of wave is 5 ms^{-1}
(d) The wavelength of wave is 0.2 m

62. Velocity of sound in air is 320 m/s. A pipe closed at one end has a length of 1 m. Neglecting end corrections, the air column in the pipe can resonate for sound of frequency. (IIT-JEE 1989)
(a) 80 Hz (b) 240 Hz
(c) 320 Hz (d) 400 Hz

63. An air column in a pipe, which is closed at one end, will be in resonance with a vibrating tuning fork of frequency 264 Hz, if the length of the column in cm is (Speed of sound in air=330 m/s) (IIT-JEE 1985)
(a) 31.25 cm (b) 62.50 cm
(c) 93.75 cm (d) 400 cm

@FAKE_PHYSEX_GRAVITON

64. Two identical straight wires are stretched so as to produce 6 beats/s when vibrating simultaneously. On changing the tension slightly in one of them, the beat frequency remains unchanged. Denoting by T_1, T_2 the higher and the lower initial tension in the strings, then it could be said that while making the above changes in tension
(IIT-JEE 1991)

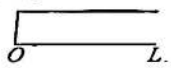
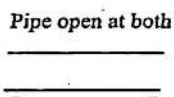
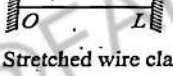
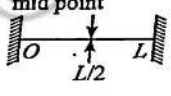
(a) T_2 was decreased (b) T_2 was increased
(c) T_1 was decreased (d) T_1 was increased

65. A person blows into open-end of a long pipe. As a result, a high-pressure pulse of air travels down the pipe. When this pulse reaches the other end of the pipe,
C-38.01 W-55.05 UA-6.94 (IIT-JEE 2012)

(a) a high-pressure pulse starts travelling up the pipe, if the other end of the pipe is open.
(b) a low-pressure pulse starts travelling up the pipe, if the other end of the pipe is open.
(c) a low-pressure pulse starts travelling up the pipe, if the other end of the pipe is closed.
(d) a high-pressure pulse starts travelling up the pipe, if the other end of the pipe is closed.

Match the Column

66. Column-I shows four systems, each of the same length L, for producing standing waves. The lowest possible natural frequency of a system is called its fundamental frequency, whose wavelength is denoted as λ_f. Match each system with statements given in Column-II describing the nature and wavelength of the standing waves. **(IIT-JEE 2011)**

Column-I	Column-II
(a) Pipe closed at one end 	(p) Longitudinal waves
(b) Pipe open at both ends 	(q) Transverse waves
(c) Stretched wires clamped at both ends 	(r) $\lambda_f = L$
(d) Stretched wire clamped at both ends and at mid point 	(s) $\lambda_f = 2L$ (t) $\lambda_f = 4L$

Numerical Types/Integer Types

67. A stationary tuning fork is in resonance with an air column in a pipe. If the tuning fork is moved with a speed of 2 ms^{-1} in front of the open end of the pipe and parallel to it, the length of the pipe should be changed for the resonance to occur with the moving tuning fork. If the speed of sound in air is 320 ms^{-1}, the smallest value of the percentage change required in the length of the pipe is_____.
C-13.45, W-59.23, UA-27.32 (JEE Adv. 2020)

68. A 20 cm long string, having a mass of 1.0 g, is fixed at both the ends. The tension in the string is 0.5 N. The string is set into vibration using an external vibrator of frequency 100 Hz. Find the separation (in cm) between the successive nodes on the string.
(IIT-JEE 2009)

69. A 3.6 m long pipe resonates with a source of frequency 212.5 Hz when water level is at certain heights in the pipe. Find the heights of water level (from the bottom of the pipe) at which resonances occur. Neglect end correction. Now the pipe is filled to a height H(=3.6 m). A small hole is drilled very close to its bottom and water is allowed to leak. Obtain an expression for the rate of fall of water level in the pipe as a function of H. If the radii of the pipe and the hole are 2×10^{-2} m and 1×10^{-3} m respectively. Calculate the time interval between the occurrence of first two resonances. Speed of sound in air is 340 m/s and $g = 10$ m/s^2 **(IIT-JEE 2000)**

70. A string 25 cm long and having a mass of 2.5 g is under tension. A pipe closed at one end is 40 cm long. When the string is set vibrating in its first overtone and the air in the pipe in its fundamental frequency, 8 beats/s are heard. It is observed that decreasing the tension in the string decreases the beat frequency. If the speed of sound in air is 320 m/s find the tension in the string.
(IIT-JEE 1982)

71. In a resonance tube experiment to determine the speed of sound in air, a pipe of diameter 5 cm is used. The air column in pipe resonates with a tuning fork of frequency 480 Hz when the minimum length of the air column is 16 cm. Find the speed of sound in air at room temperature.

Fill in the Blanks

72. A cylinder resonance tube open at both ends has fundamental frequency f in air. Half of the length of the tube is dipped vertically in water. The fundamental frequency of the air column now is .....
(IIT-JEE 1992)

73. In a sonometer wire, the tension is maintained by suspending a 50.7 kg mass from the free end of the wire. The suspended mass has a volume of 0.0075 m^3. The fundamental frequency of vibration of the wire is 260 Hz. If the suspended mass is completely submerged in water, the fundamental frequency will become _____ Hz.
(IIT-JEE 1987)

Subjective

74. The air column in a pipe closed at one end is made to vibrate in its second overtone by tuning fork of frequency 440 Hz. The speed of sound in air is 330 m/s. End corrections may be neglected. Let p_0 denote the mean pressure at any point in the pipe and Δp_0 the maximum amplitude of pressure variation. **(IIT-JEE 1998)**

(a) Find the length L of the air column.
(b) What is the amplitude of pressure variation at the middle of the column?
(c) What are the maximum and minimum pressures at the open end of the pipe?
(d) What are the maximum and minimum pressures at the closed end of the pipe?

75. A metallic rod of length 1 m is rigidly clamped at its mid-point. Longitudinal stationary waves are set-up in the rod in such a way that there are two nodes on either side of the midpoint. The amplitude of an antinode is 2×10^{-6} m. Write the equation of motion at a point 2 cm from the mid-point and those of the constituent waves in the rod. (Young's modulus of the material of the rod = 2×10^{11} Nm^{-2}; density = 8000 kg m^{-3}) **(IIT-JEE 1994)**

@FAKE_CBSE_X_@MAILED.NET

76. The vibration ... length 60 cm fixed at both ends are represented by the equation

$$y = 4\sin\left(\frac{\pi x}{15}\right)\cos(96\pi t)$$

where, x and y are in cm and t is in second. **(IIT-JEE 1985)**

(a) What is the maximum displacement of a point at $x = 5$ cm?
(b) Where are the nodes located along the string?
(c) What is the velocity of the particle at $x = 7.5$ cm at $t = 0.25$ s?
(d) Write down the equations of the component waves whose superposition gives the above wave.

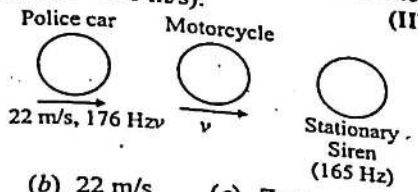
Doppler's Effect

Single Correct

77. A police car with a siren of frequency 8kHz is moving with uniform velocity 36 km/h towards a tall building which reflects the sound waves. The speed of sound in air is 320 m/s. The frequency of the siren heard by the car driver is **(JEE Adv. 2011)**

(a) 8.50kHz (b) 8.25kHz (c) 7.75kHz (d) 7.50kHz

78. A police car moving at 22 m/s chases a motorcyclist. The policeman sounds his horn at 176 Hz, while both of them move towards a stationary siren of frequency 165 Hz. Calculate the speed of the motorcycle, if it is given that the motorcyclist does not observe any beats (speed of sound =330 m/s). **(IIT-JEE 2003)**



(a) 33 m/s (b) 22 m/s (c) Zero (d) 11 m/s

79. A siren placed at a railway platform is emitting sound of frequency 5kHz. A passenger sitting in a moving train A records a frequency of 5.5kHz, while the train approaches the siren. During his return journey in a different train B he records a frequency of 6.0 kHz while approaching the same siren. The ratio of the velocity of train B to that of train A is **(IIT-JEE 2002)**

(a) 242/252 (b) 2 (c) 5/6 (d) 11/6

80. A whistle giving out 450 Hz approaches a stationary observer at a speed of 33 m/s. The frequency heard by the observer (in Hz) is (Speed of sound = 330 m/s) **(IIT-JEE 1997)**

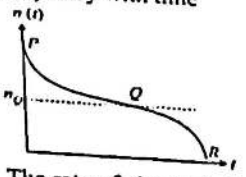
(a) 409 (b) 429 (c) 517 (d) 500

Multiple Correct

81. Two loudspeakers M and N are located 20 m apart and emit sound at frequencies 118 Hz and 121 Hz, respectively. A car in initially at a point P, 1800 m away from the midpoint Q of the line MN and moves towards Q constantly at 60 km/h along the perpendicular bisector of MN. It crosses Q and eventually reaches a point R, 1800 m away from Q. Let $v(t)$ represent the beat frequency measured by a person sitting in the car at time t. Let v_P, v_Q and v_R be the beat frequencies measured at locations P, Q and R respectively. The speed of sound in air is 330 ms^{-1}. Which of the following statement(s) is (are) true regarding the sound heard by the person?

C-7.09 W-12.77 UA-56.65 PC-23.49 (JEE Adv. 2016)

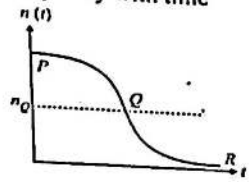
(a) The plot below represents schematically the variation of beat frequency with time



(b) The rate of change in beat frequency is maximum when the car passes through Q

(c) $v_P + v_R = 2v_Q$

(d) The plot below represents schematically the variations of beat frequency with time



82. A sound wave of frequency f travels horizontally to the right. It is reflected from a large vertical plane surface moving to left with a speed v. The speed of sound in medium is c **(IIT-JEE 1995)**

(a) The number of waves striking the surface per second is $f\frac{(c+v)}{c}$

(b) The wavelength of reflected wave is $\frac{c(c-v)}{f(c+v)}$

(c) The frequency of the reflected wave is $f\frac{(c+v)}{(c-v)}$

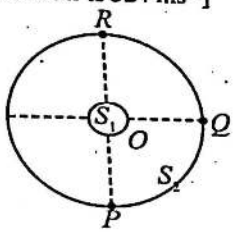
(d) The number of beats heard by a stationary listener to the left of the reflecting surface is $\frac{vf}{c-v}$

Comprehension Based/Passage Based

Comprehension-(83 to 84)

S_1 and S_1 are two identical sound sources of frequency 656 Hz. The source S_1 is located at O and S_2 moves anti-clockwise with a uniform speed $4\sqrt{2}$ ms^{-1} on a circular path around O, as shown in the figure. There are three points P, Q and R on this path such that P and R are diametrically opposite while Q is equidistant from them. A sound detector is placed at point P. The source S_1 can move along direction OP. **(JEE Adv. 2023)**

[Given: The speed of sound in air is 324 ms^{-1}]



83. When only S_2 is emitting sound and it is Q, the frequency of sound measured by the detector in Hz is _____.

C-11.95 W-56.87 UA-31.18

84. Consider both sources emitting sound. When S_2 is at R and S_1 approaches the detector with a speed 4ms^{-1}, the beat frequency measured by the detector is _____Hz.

C-14.41 W-53.97 UA-31.63

@RAKESH_SIR_X @RAJ_EDUNET

85. A source, approaching with speed u towards the open end of a stationary pipe of length L, is emitting a sound of frequency f_s. The farther end of the pipe is closed. The speed of sound in air is v and f_0 is the fundamental frequency of the pipe. For which of the following combination(s) of u and f_s, will the sound reaching the pipe lead to a resonance?

C-10.92 W-23.99 UA-54.96 PC-10.13 (JEE Adv. 2021)

(a) $u = 0.8v$ and $f_s = f_0$

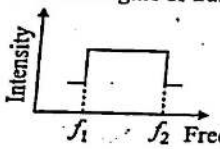
(b) $u = 0.8v$ and $f_s = 2f_0$

(c) $u = 0.8v$ and $f_s = 0.5f_0$

(d) $u = 0.5v$ and $f_s = 1.5f_0$

Comprehension-(86 to 87)

Two trains A and B are moving with speeds 20 m/s and 30 m/s respectively in the same direction on the same straight track, with B ahead of A. The engines are at the front ends. The engine of train A blows a long whistle.



Assume that the sound of the whistle is composed of components varying in frequency from $f_1 = 800$ Hz to $f_2 = 1120$ Hz, as shown in the figure. The spread in the frequency (highest frequency-lowest frequency) is thus 320 Hz. The speed of sound in air is 340 m/s.

86. The speed of sound of the whistle is **(IIT-JEE 2007)**

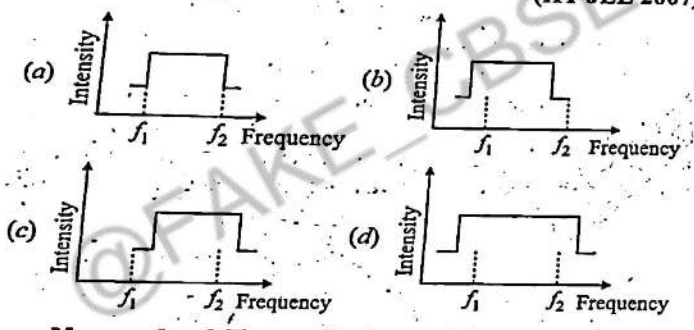
(a) 340 m/s for passengers in A and 310 m/s for passengers in B

(b) 360 m/s for passengers in A and 310 m/s for passengers in B

(c) 310 m/s for passengers in A and 360 m/s for passengers in B

(d) 340 m/s for passengers in both the trains

87. The distribution of the sound intensity of the whistle as observed by the passengers in train A is best represented by **(IIT-JEE 2007)**



Numerical Types/Integer Types

88. A train S_1, moving with a uniform velocity of 108 km/h, approaches another train S_2 standing on a platform. An observer O moves with a uniform velocity of 36 km/h towards S_2, as shown in figure. Both the trains are blowing whistles of same frequency 120 Hz. When O is 600 m away from S_2 and distance between S_1 and S_2 is 800 m, the number of beats heard by O is ____. [Speed of the sound = 330 m/s]

C-15, W-62, UA-23 (JEE Adv. 2019)

89. Two men are walking along a horizontal straight line in the same direction. The man in front walks at a speed 1.0 ms^{-1} and the man behind walks at a speed 2.0 ms^{-1}. A third man is standing at a height 12 m above the same horizontal line such that all three men are in a vertical plane. The two walking men are blowing identical whistles which emit a sound of frequency 1430 Hz. The speed of sound in air 330 ms^{-1}. At the instant, when the moving men are 10 m apart, the stationary man is equidistant from them. The frequency of beats in Hz, heard by the stationary man at this instant, is

C-9.57 W-67.14 UA-23.29 (JEE Adv. 2018)

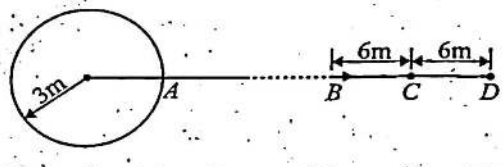
90. A stationary source emits sound of frequency $f_0 = 492$ Hz. The sound is reflected by a large car approaching the source with a speed of 2 ms^{-1}. The reflected signal is received by the source and superposed with the original. What will be the beat frequency of the resulting signal in Hz? (Given that the speed of sound in air is 330 ms^{-1} and the car reflects the sound at the frequency it has received).

C-23.37 W-71.07 UA-5.56 (JEE Adv. 2017)

91. An observer standing on a railway crossing receives frequency of 2.2kHz and 1.8kHz when the train approaches and recedes from the observer. Find the velocity of the train. (The speed of the sound in air is 300 m/s.) **(IIT-JEE 2005)**

92. A whistle emitting a sound of frequency 440 Hz is tied to a string of 1.5 m length and rotated with an angular velocity of 20 rad/s in the horizontal plane. Calculate the range of frequencies heard by an observer stationed at a large distance from the whistle. (Speed of sound =330 m/s). **(IIT-JEE 1996)**

93. A source of sound is moving along a circular path of radius 3 m with an angular velocity of 10 rad/s. A sound detector located far away from the source is executing linear simple harmonic motion along the line BD (see figure) with an amplitude $BC = CD = 6$ m. The frequency of oscillation of the detector is $5/\pi$ per second. The source is at the point A when the detector is at the point B. If the source emits a continuous sound wave of frequency 340 Hz, find the maximum and the minimum frequencies recorded by the detector. (Speed of sound = 340 m/s) **(IIT-JEE 1990)**



94. Two tuning forks with natural frequencies of 340 Hz each move relative to a stationary observer. One fork moves away from the observer, while the other moves towards him at the same speed. The observer hears beats of frequency 3 Hz. Find the speed of the tuning fork. Speed of sound =340 m/s. **(IIT-JEE 1986)**

95. A sonometer wire under tension of 64 N vibrating in its fundamental mode is in resonance with a vibrating tuning fork. The vibrating portion of the sonometer wire has a length of 10 cm and mass of 1 g. The vibrating tuning fork is now moved away from the vibrating wire with a constant speed and an observer standing near the sonometer hears one beat per second. Calculate the speed with which the tuning fork is moved, if the speed of sound in air is 300 m/s. **(IIT-JEE 1983)**

96. A source of sound of frequency 256 Hz is moving rapidly towards a wall with a velocity of 5 m/s. How many beats per second will be heard by the observer on the source itself if sound travels at a speed of 330 m/s? **(IIT-JEE 1981)**

@FAKE_CBSE_X_@_TELEGRAM

Fill in the Blanks

97. A bus is moving towards a huge wall with a velocity of 5 ms^{-1}. The driver sounds a horn of frequency 200 Hz. The frequency of the beats heard by a passenger of the bus will be ____ Hz. (Speed of sound in air = 342 ms^{-1}) **(IIT-JEE 1992)**

True/False

98. A source of sound with frequency 256 Hz is moving with a velocity 5m/s towards a wall and an observer is stationary between the source and the wall. When the observer is between the source and the wall he will hear beats.(The speed of sound is 330 m/s.)**(IIT-JEE 1985)**

Subjective

99. Two narrow cylindrical pipes A and B have the same length. Pipe A is open at both ends and is filled with a mono atomic gas of molar mass M_A. Pipe B is open at one end and closed at the other end, and is filled with a diatomic gas of molar mass M_B. Both gases are at the same temperature.
   (*a*) If the frequency to the second harmonic of pipe A is equal to the frequency of the third harmonic of the fundamental mode in pipe B, determine the value of M_A/M_B.
   (*b*) Now the open end of the pipe B is closed (so that the pipe is closed at both ends). Find the ratio of the fundamental frequency in pipe A to that in pipe B. **(IIT-JEE 2002)**

100. A boat is travelling in a river with a speed 10 m/s along the stream flowing with a speed 2 m/s. From this boat a sound transmitter is lowered into the river through a rigid support. The wavelength of the sound emitted from the transmitter inside the water is 14.45 mm. Assume that attenuation of sound in water and air is negligible. **(IIT-JEE 2001)**
   (*a*) What will be the frequency detected by a receiver kept inside the river downstream?
   (*b*) The transmitter and the receiver are now pulled up into air. The air is blowing with a speed 5 m/s in the direction opposite to the river stream. Determine the frequency of the sound detected by the receiver.
   (Temperature of the air and water = 20°C; Density of river water = 10^3 kg/m^3;
   Bulk modulus of the water = 2.088×10^9 Pa;
   Gas constant $R = 8.31$ J/mol – K;
   Mean molecular mass of air = 28.8×10^{-3} kg/mol;
   C_p / C_v for air = 1.4)

101. A band playing music at a frequency f is moving towards a wall at a speed v_b. A motorist is following the band with a speed v_m. If v is the speed of sound. Obtain an expression for the beat frequency heard by the motorist. **(IIT-JEE 1997)**

102. A train approaching a hill at a speed of 40 km/h sounds a whistle of frequency 580 Hz when it is at a distance of 1 km from a hill. A wind with a speed of 40 km/h is blowing in the direction of motion of the train. Find **(IIT-JEE 1988)**
   (*a*) The frequency of the whistle as heard by an observer on the hill,
   (*b*) The distance from the hill at which the echo from the hill is heard by the driver and its frequency.
   (Velocity of sound in air =1200 km/h)

@TAKE_CBSE_X@RKS_EDUMEDIA

ANSWER KEY

JEE-Main

1. (*b*)	2. [1152]	3. [20]	4. (*b*)	5. (*b*)	6. [7]	7. (*b*)	8. (*b*)	9. (*a*)	10. (*b*)
11. (*c*)	12. [90]	13. (*c*)	14. (*a*)	15. [1215]	16. [1]	17. (*c*)	18. (*d*)	19. (*d*)	20. (*c*)
21. (*d*)	22. (*c*)	23. [13]	24. (*a*)	25. [5]	26. (*a*)	27. (*d*)	28. (*b*)	29. (*b*)	30. [400]
31. (*c*)	32. [60]	33. [80]	34. [60]	35. [500]	36. [5]	37. [3]	38. [2]	39. [10]	40. [1]
41. (*b*)	42. (*b*)	43. (*c*)	44. [35]	45. (*d*)	46. (*d*)	47. (*b*)	48. (Bonus)	49. (*a*)	50. [740]
51. (*a*)	52. [294.00]	53. (*d*)	54. [6]	55. [16]	56. [1]	57. [900]	58. [104]	59. [80]	60. [50]
61. (*d*)	62. [4]	63. [34]	64. (*a*)	65. [106]	66. [0.62 to 0.63]		67. (*c*)	68. (*c*)	

JEE-Advanced

1. (*b, c, d*)	2. (*a, b, c, d*)	3. (*a, c, d*)	4. [5]	7. (*a*)	8. (*c*)	9. (*a*)	10. (*a*)	11. (*b*)	12. (*a, c*)
13. (*b, c*)	14. (*a, b, c, d*)	15. [3]	16. [0.5]	17. [0.12]	19. (*b*)	20. (*b*)	21. (*b*)	23. (*a*)	24. (*a*)
25. (*a*)	26. (*c*)	27. (*a, c, d*)	28. (*a, b, c*)	29. (*b, c*)	30. [5]	31. [11]	37. (*a*)	38. (*b*)	39. (*c*)
40. (*a, b, c*)	42. [False]	43. (*b*)	44. (*b*)	45. [True]	46. (*d*)	47. (*b*)	48. (*b*)	49. (*a*)	50. (*a*)
51. (*d*)	52. (*b*)	53. (*c*)	54. (*b*)	55. (*d*)	56. (*a*)	57. (*c*)	58. (*a*)	59. (*c*)	60. (*a, d*)
61. (*a,b,c,d*)	62. (*a,b,d*)	63. (*a, c*)	64. (*b, c*)	65. (*b, d*)	66. (*A - p, t; B - p, s; C - q, s; D - q, r*)			67. [0.62 to 0.63]	
68. [5]	69. [43]	70. [27.04]	71. [336]	77. (*a*)	78. (*b*)	79. (*b*)	80. (*d*)	81. (*b, c, d*)	82. (*a, b, c*)
83. [648]	84. [8.2]	85. (*a, d*)	86. (*b*)	87. (*a*)	88. [8]	89. [5]	90. [6]	91. [30]	
92. [403, 484]		93. [257 Hz, 438 Hz]		94. [1.5]	95. [0.75]	96. [7.88]	98. [True]		

EXPLANATIONS

JEE-Main

1. (*b*) We have given the plane progressive wave equation,
$y = 2\cos 2\pi(330\,t - x)$ m
$y = A\cos(\omega t - kx)$
by comparing $\omega = 2\pi \times 330$
$2\pi f = 2\pi \times 330$
$f = 330$

2. [1152] Comparing the given eq^n with
$Y = Y_0 \sin(\omega t - kx + \phi)$
$W = 2\pi \times 60$
$K = 2\pi \times 0.5$
$V = \frac{\omega}{k} = \frac{2\pi\times 60}{2\pi\times 0.5} = \frac{160}{0.5}$ m/s
$= 320 \times \frac{18}{5}$ km/h $= 1152$ km/h

3. [20] wave velocity $v = \frac{\omega}{k}$
$= \frac{6}{0.003\times 10^2} = 20\,ms^{-1}$

4. (*b*) The equation of longitudinal wave is given as,
$x = 10\sin 2\pi\left(nt - \frac{x}{\lambda}\right)cm$
We know that, wave velocity, $v = \frac{\omega\lambda}{2\pi}$
$\Rightarrow 10\times 2\pi n = 4\times\frac{\omega\lambda}{2\pi}$
$\Rightarrow 10\times\pi\, n = 4\times n\lambda \Rightarrow \lambda = 5\pi$

5. (*b*) We know that, travelling wave can be represented as $f\left(t \pm \frac{x}{v}\right)$
Thus, $y = A\sin(15x - 2t)$ represents a travelling wave.

6. [7] Phase difference between the two waves,
$\phi = kx_0 = 6.28 \times 3.5 = 7\pi$ rad
Amplitude of resulting wave,
$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$
$= \sqrt{12^2 + 5^2 + 2\times 12\times 5\times\cos(7\pi)} = 7$

7. (*b*) We know, distance between trough to crest $= (2n_1 + 1)\frac{1}{2}$
Distance between crest to crest $= n_2\lambda$
$\frac{1.5}{5} = \frac{(2n_1+1)}{2n_2}$
$3n_2 = 10n_1 + 5$, $n_1 = 1, n_2 = 5 \rightarrow \lambda = 1$
$n_1 = 4, n_2 = 15 \rightarrow \lambda = \frac{1}{3}$, $n_1 = 7, n_2 = 25 \rightarrow \lambda = \frac{1}{5}$

8. (*b*) $\Delta u = \frac{4q^2}{4\pi\varepsilon_0}\left[\frac{1}{3d/2} - \frac{1}{d/2}\right]$
$\Delta u = -\frac{4q^2}{3\pi\varepsilon_0 d}$

9. (*a*) $50t + 2x = \text{constant}$
$50 + \frac{2dx}{dt} = 0$
$v = \frac{dx}{dt} = -25\ m/s$

10. (*b*) $\therefore v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{70}{7\times 10^{-3}}} = 100$ m/s

11. (*c*) From the given equation $k = 8\ m^{-1}$ and $\omega = 4\ rad/s$
Velocity of wave $= \frac{\omega}{k}$
$v = \frac{4}{8} = 0.5\,m/s$

12. [90]

Fundamental frequency $f_0 = 50$ Hz and $\mu = 20$ g/m
$m = 18\ g$
$\therefore$ length of string $l = \frac{m}{\mu} = \frac{18}{20}m = \frac{9}{10}m$
From diagram $\frac{\lambda}{2} = \ell$
$\Rightarrow \lambda = 2\ell = \frac{9}{5}m$
again speed $v = f_0\lambda = 50\times\frac{9}{5} = 90$ m/s

13. (*c*) We have, $y = 0.5\sin\frac{2\pi}{\lambda}(400t - x)m$
So, $\omega = \frac{2\pi}{\lambda}\times 400$ and $K = \frac{2\pi}{\lambda}$
$\therefore$ Wave speed, $V = \frac{\omega}{k} = 400\,m/s$

14. (*a*) For a wave, $y = A\sin(\omega t + kx)$
Maximum particle velocity, $v_{max} = A\omega$
Wave velocity, $v = \upsilon\lambda$
So, $\upsilon\lambda = A\omega$
$\Rightarrow \lambda = \frac{A\omega}{\upsilon} = \frac{A\omega}{\frac{\omega}{2\pi}}$ $\left[\because \upsilon = \frac{\omega}{2\pi}\right]$
$\Rightarrow \lambda = 2\pi A = 4\pi$ $(\because A = 2$ given$)$

15. [1215] Speed, $v = \frac{\omega}{k} = \frac{30}{1} = 30\,m/s$
$v = \sqrt{\frac{T}{\mu}} \Rightarrow T = \mu v^2 = \frac{0.135\times 10^{-1}}{10^{-1}}\times(30)^2$
$= 12.15$ N $= 1215 \times 10^{-2}\,N$

16. [1] The equation of wave at any time t can be written as, $y = \frac{1}{1+(x-vt)^2}$
Comparing above equation,
$y = \frac{1}{1+(x-2)^2}$,
we get $v = 1$m/s

17. (*c*) Here, we have $v \propto \sqrt{T}$ [T is tension in the wire]
$\Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} \Rightarrow \frac{v}{(v/2)} = \sqrt{\frac{2.06\times 10^4}{T}}$
$\Rightarrow T = \frac{2.06\times 10^4}{4}N = 0.515\times 10^4\,N$
$= 5.15\times 10^3\,N$

18. (*d*) $f_3 = \frac{3}{2L}\sqrt{\frac{T}{\mu}}$
$240 = \frac{3}{2\times 2}v$, $v = 320$ m/s
$f_1 = \frac{1}{2L}v = \frac{1}{2\times 2}\times 320 = 80$ Hz

19. (*d*) Speed of wave
$v = \frac{(\text{coefficient of } t)}{(\text{coefficient of } x)} = \frac{1000}{3}$
Since speed of wave $\propto \sqrt{T}$
$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} = \frac{\frac{1000}{3}}{336} = \sqrt{\frac{273}{T}}$
$T = 277.41$ k $= 4.4°$C

DHARE_CBSE_X @RAJ_FIZWET

20. (c) $v=\frac{\omega}{k}=\frac{450}{9}=50\,\text{ms}^{-1}$

$v=\sqrt{\frac{T}{\mu}}$, $T=v^2\mu=50^2\times5\times10^{-3}$

$=12.5\,N$

21. (d) $V=\sqrt{\frac{T}{\mu}}=\sqrt{\frac{8}{5\times10^{-3}}}=40\,\text{m/s}$

$\lambda=\frac{V}{f}=\frac{40}{100}\text{m}=0.4\,\text{m}$

Separation between 2 successive node

$=\frac{\lambda}{2}=20\,\text{cm}$

22. (c) $I=\frac{1}{2}\varepsilon_0E_0^2C$ ...(i)

$0.96\,I=\frac{1}{2}E_0'^2V$ ...(ii)

$\Rightarrow 0.96=\left(\frac{E_0'}{E_0}\right)^2\frac{\varepsilon}{\varepsilon_0}\frac{v}{C}$

$0.96=\left(\frac{E_0'}{E_0}\right)^2\frac{\varepsilon}{\varepsilon_0}\frac{1}{1.5}$

$0.96=\left(\frac{E_0'}{E_0}\right)^2\varepsilon_r\frac{1}{1.5}$ ...(iii)

and $v=\frac{1}{\sqrt{\mu_0\varepsilon_0\mu_r\varepsilon_r}}$; $v=\frac{C}{\sqrt{\mu_r\varepsilon_r}}$

$\sqrt{\mu_r\varepsilon_r}=\frac{C}{v}$; $\sqrt{\varepsilon_r}=1.5$; $\mu_r\approx1$

for transparent medium.

From equation (iii)

$0.96=\left(\frac{E_0'}{E_0}\right)^2(1.5)^2\left(\frac{1}{1.5}\right)$

$\Rightarrow E_0'=24\,\text{V/m}$

23. [13]

Intensity for incoherent wave

$I_1=I_A+I_B\Rightarrow I_1=I_0+9I_0$

$I_1=10I_0$

Intensity for coherent wave

$I_2=I_A+I_B+2\sqrt{I_AI_B}\cos60°$

$I_2=I_0+9I_0+2\sqrt{9I_0^2}\cdot\frac{1}{2}=13I_0$

$\frac{I_1}{I_2}=\frac{10}{13}$

24. (a) $y_1=5\sin2\pi(x-vt)$ cm, $y_2=3\sin2\pi(x-vt+1.5)$ cm

phase angle, $\phi=2\pi\times1.5=3\pi$

$\therefore A=\sqrt{A_1^2+A_2^2+2A_1A_2\cos\phi}$

$=\sqrt{5^2+3^2+2\times5\times3\cos3\pi}$

$=\sqrt{25+9+(30\times-1)}=\sqrt{4}=2\,\text{cm}$

25. [5] At $x=\frac{4}{3}$cm

$y=10\cos\frac{4\pi}{3}.\sin\frac{2\pi t}{T}$

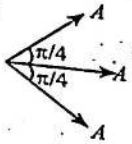
$=10\cos\left(\pi+\frac{\pi}{3}\right).\sin\frac{2\pi t}{T}$

$=-10\cos\frac{\pi}{3}.\sin\left(\frac{2\pi t}{T}\right)$

$=-5\sin\left(\frac{2\pi t}{T}\right)$cm

Hence, Amplitude will be 5 cm.

26. (a)



$A_{res}=\left(\sqrt{2}+1\right)A$

$I_{res}=\left(\sqrt{2}+1\right)^2I_0=\left(3+2\sqrt{2}\right)I_0=5.8\,I_0$

27. (d) $f_{beat}=11-9=2\,\text{Hz}$

$\therefore$ Time period of oscillation of amplitude

$=\frac{1}{f_{beat}}=\frac{1}{2}$

Although the graph of oscillation is not given, the equation of envelope is given by option (d)

28. (b) $\left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right)=\frac{16}{1}$; $\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}=\frac{4}{1}$

$\Rightarrow 3\sqrt{I_1}=5\sqrt{I_2}$

$\Rightarrow \frac{I_1}{I_2}=\frac{25}{9}$

29. (b) Wave speed, Since, car in at west, $a=0\Rightarrow T=Mg$.

$v=\left(\frac{T}{\mu}\right)=\sqrt{M\frac{g}{\mu}}$ ...(i)

Similarly, when the car is moving with acceleration a, horizontal pseudo force acts on the mass in addition to vertical Mg

$\therefore\ 60.5=\sqrt{\frac{M(g^2+a^2)^{1/2}}{\mu}}$ ...(ii)

diving (ii) by (i) we get

$\frac{\sqrt{g^2+a^2}}{g}=\left(\frac{60.5}{60}\right)^2$

(using binomial expansion

$1+\frac{1}{2}\frac{a^2}{g^2}=1+\frac{1}{60}$

$\Rightarrow a=\frac{g}{\sqrt{30}}\approx\frac{g}{5}$

30. [400] $\frac{V}{4\ell_1}=30\Rightarrow\ell_1=\frac{11}{4}$ m

$\frac{V}{4\ell_2}=110\Rightarrow\ell_2=\frac{3}{4}m$

$\Delta l=2m$,

Change in volume $=4\Delta l=400\,\text{cm}^3$

$M=400g$; ($\because\rho=1\,\text{g/cm}^3$)

31. (c) By comparing given equation with standard equation

we get, $\frac{2\pi n}{\lambda}=\omega\ \&\ \frac{2\pi}{\lambda}=k$

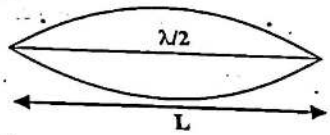
$\left[\frac{n}{\lambda}\right]=[\omega]=T^{-1}$

and $[nt]=[\lambda]=L$

$\Rightarrow[n]=[\lambda\omega]=LT^{-1}$

$\Rightarrow[x]=[\lambda]=L$

32. [60]



Here, given that $f_0=400$ Hz

Speed, $v=\sqrt{\frac{T}{\mu}}=$ constant

$\frac{\lambda}{2}=L; v=f_0\lambda$

$\frac{v}{2f_0}=L\Rightarrow v=2Lf_0$

$L'=\frac{V}{2f'}=\frac{2Lf_0}{2f'}$

$=\frac{Lf_0}{f'}=\frac{90\times400}{600}=60\,\text{cm}$

33. [80]

$f=\frac{1}{2L}\sqrt{\frac{T}{\mu}}=\frac{1}{2L}\sqrt{\frac{YA\Delta L}{\rho AL}}=\frac{1}{2L}\sqrt{\frac{Y\Delta L}{\rho L}}$

$f=\frac{1}{2\times0.5}\times\sqrt{\frac{8\times10^{10}\times3.2\times10^{-4}}{8\times10^3\times0.5}}$

$f=80$ Hz

@FAKE_CBSE_X @RAJ_BUNET

34. [60] Fundamental frequency, $f = \frac{v}{2\ell}$.

$f \propto \frac{1}{\ell}$

$\frac{f_1}{f_2} = \frac{\ell_2}{\ell_1} \Rightarrow l_2 = \frac{f_1}{f_2} \times l_1$

$\Rightarrow l_2 = \frac{120}{180} \times 90 = 60$ cm

$\ell_2 = 60$ cm

35. [500]

Frequency of the string $f = \frac{1}{2\ell}\sqrt{\frac{T}{\mu}}$

(T: Tension)

$\frac{f_2}{f_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{mg}{180g}}$

$\left(\frac{50}{30}\right)^2 = \frac{m}{180} \Rightarrow m = \frac{25}{9} \times 180 = 500$ gram

36. [5] $f = \frac{n}{2\ell}\sqrt{\frac{T}{\mu}}$

Successive harmonics are $f_{(n)}$ and $f_{(n+1)}$

$f_{(n)} = \frac{n}{2}\sqrt{\frac{T}{\mu}} = 750$ ...(i)

$f_{(n+1)} = \frac{n+1}{2}\sqrt{\frac{T}{\mu}} = 1000$ ...(ii)

$\because f_{(n+1)} - f_{(n)} = 1000 - 750 = 250$ Hz

$\therefore \frac{n+1}{2}\sqrt{\frac{T}{\mu}} - \frac{n}{2}\sqrt{\frac{T}{\mu}} = 250$

$\sqrt{\frac{T}{\mu}} = 500$

$\Rightarrow T = (500)^2 \mu \Rightarrow T = (500)^2 (2 \times 10^{-5})$

$\Rightarrow T = 5$N

37. [3] For n^{th} harmonic, $\frac{nv}{0.6} = 400$

For $(n+1)^{th}$ harmonic $\frac{(n+1)v}{0.6} = 450$

$\Rightarrow \left[\frac{0.6 \times 450}{v} + 1\right]\frac{v}{0.6} = 450$

$\Rightarrow v = 30$

$\Rightarrow v = \sqrt{\frac{T}{\mu}} \Rightarrow v^2 = \frac{T}{\mu}$

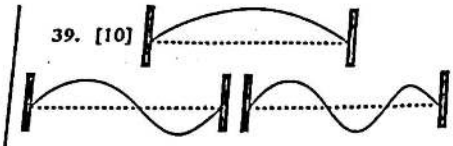
$\Rightarrow \frac{2700}{\mu} = 900$

$\mu = 3$

38. [2] $v = \sqrt{\frac{T}{\mu}}$, $v' = \sqrt{\frac{1.04T}{\mu}}$

% change $= \left(\sqrt{1.04} - 1\right) \times 100 = 2\%$

39. [10]



$\therefore \ell = n\frac{\lambda}{2}$ (for wire fixed at both ends)

$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{900}{9 \times 10^{-4}}} = 1000$ m/s

$\therefore v = f\lambda$ or $\frac{v}{\lambda} = f \Rightarrow f_0 = \frac{nv}{2\ell}$

$f' = \frac{(n+1)v}{2\ell}$

$\frac{500\,Hz}{550\,Hz} = \frac{\frac{n \times 1000}{2\ell}}{\frac{(n+1) \times 1000}{2\ell}} \Rightarrow n = 10$

$\therefore 500\,Hz = \frac{10 \times 1000}{2 \times \ell}$

$\Rightarrow \ell = 10$ m

Hence, length of the wire is 10 m.

40. [1] From given equation, $K = 1.57$ cm^{-1}

$kx = \pi/2$

$\Rightarrow 1.57x = \frac{\pi}{2} = \frac{3.14}{2} = 1.57$

$x = 1$cm

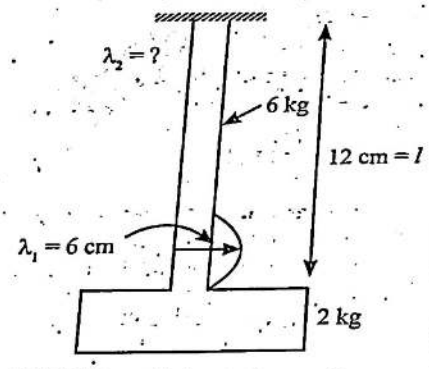
41. (b) As we know that velocity of vibration of string $v = \sqrt{\frac{T}{\mu}}$

Here, $T_1 = 2g$, $T_2 = 8g$

As wave velocity $v = f \times \lambda$

$\Rightarrow v \propto \lambda \propto \sqrt{T} \Rightarrow \frac{\lambda_2}{\lambda_1} = \frac{\sqrt{T_2}}{\sqrt{T_1}}$

$\Rightarrow \lambda_2 = \lambda_1 \frac{\sqrt{T_2}}{\sqrt{T_1}} = 12$ cm



42. (b) We Know that,

$f_x = \frac{1}{2\ell}\sqrt{\frac{T_x}{\mu}}$; $f_z = \frac{1}{2\ell}\sqrt{\frac{T_y}{\mu}}$

Here, $f \propto \sqrt{T}$

$\frac{f_x}{f_z} = \frac{450}{300} = \sqrt{\frac{T_x}{T_z}} \Rightarrow T_x/T_z = 9/4 = 2.25$

Hence, option (b) is correct answer

43. (c) Fundamental frequency = 490 − 420 = 70 Hz

$70 = \frac{1}{2\ell}\sqrt{\frac{T}{\mu}}$

($\because \mu$ is mass per unit length and T is tension in the wire)

$\Rightarrow 70 = \frac{1}{2\ell}\sqrt{\frac{540}{6 \times 10^{-3}}}$

$\Rightarrow \ell = \frac{1}{2 \times 70}\sqrt{90 \times 10^3} = \frac{300}{140} = 2.14$ m

44. [35] Given: $\rho = 9 \times 10^{-3}$ kg cm^{-3}

$\Delta\ell = 4.9 \times 10^{-4}$

Young' modulus $= 9 \times 10^{10}$ Nm^{-2}

Length of stretched wire = 1 m

We know that frequency (f) $= \frac{1}{2\ell}\sqrt{\frac{Y\Delta\ell}{\rho\ell}}$

$= \frac{1}{2 \times 1}\sqrt{\frac{9 \times 10^{10} \times 4.9 \times 10^{-4}}{9000 \times 1}} = 35$ Hz

45. (d)

$\therefore \mu_1 = \frac{\rho\pi r^2 L}{L} = \mu$ and $\mu_2 = \frac{\rho 4\pi r^2 L}{L} = 4\mu$

Tension in both are the same = T

Let the speed of the wave in the wires be V_1 and V_2.

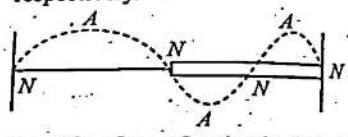
$V_1 = \sqrt{\frac{T}{\mu}} = V$, $V_2 = \sqrt{\frac{T}{4\mu}} = \frac{V}{2}$

So fundamental frequencies in both wires are

$f_1 = \frac{V_1}{2L} = \frac{V}{2L}$ and $f_2 = \frac{V_2}{2L} = \frac{V}{4L}$

Frequency at which both resonate is L.C.M. of both frequencies i.e., $\frac{V}{2L}$.

Hence no. of loops in wires are 1 and 2 respectively.



So, ratio of no. of antinodes is 1 : 2.

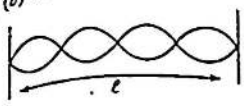
46. (d) Force on the surface (25% reflecting and rest absorbing)

$F = \frac{25}{100}\left(\frac{2I}{c}\right) + \frac{75}{100}\left(\frac{I}{c}\right) = \frac{125}{100}\left(\frac{I}{c}\right)$

$= \frac{125}{100} \times \left(\frac{50}{3 \times 10^8}\right) = 20.83 \times 10^{-8}$ N

@FAKE_CBSE_X @RAJ_EDUNET

47. (b) 4th harmonic



$4\frac{\lambda}{2} = \ell$

$2\lambda = \ell$

$\frac{2\pi}{\lambda} = 0.157 \Rightarrow \lambda = 40$

$\therefore \ell = 2\lambda = 80$ m

48. (Bonus)
Question is wrong as data is incomplete.

49. (a) The speed of sound in an ideal gas is given by

$v = \sqrt{\frac{\gamma RT}{M}} = \sqrt{\frac{1.4 \times 8.3 \times 273}{32 \times 10^{-3}}}$

$= 314.8541 = 315$ m/s

50. [740]
n^{th} Frequency in open organ pipe

$f = \frac{nv}{2L}$

Difference in freuency

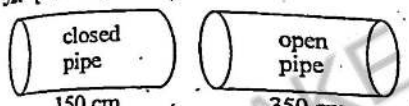
$\Delta f = \frac{6v}{2 \times 0.6} - \frac{5v}{2 \times 0.9}$ ($\because v = 333$ m/s)

$f = 740$ Hz

51. (a) $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \frac{1}{\sqrt{M}}$

$\frac{v_{H_2}}{v_{O_2}} = \sqrt{\frac{32}{2}} = \sqrt{\frac{16}{1}} = \frac{4}{1}$

52. [294.00]



$f_o = \frac{v}{2\ell_2}$ and $f_c = \frac{v}{4\ell_1}$

$\frac{v}{4 \times 150} - \frac{v}{2 \times 350} = 7$

$[\text{Here}, |f_c - f_0| = 7]$

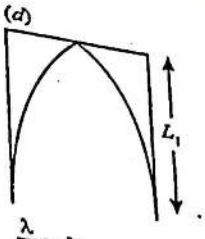
$\frac{v}{600\,\text{cm}} - \frac{v}{700\,\text{cm}} = 7$

$\Rightarrow \frac{v}{6\,\text{m}} - \frac{v}{7\,\text{m}} = 7$

$v\left(\frac{1}{42}\right) = 7$

$\Rightarrow v = 42 \times 7 = 294$ m/s

53. (d)



$\frac{\lambda}{4} = L_1$

$2\left(\frac{\lambda}{2}\right) = \lambda$

$v = f\lambda \Rightarrow v = f_1(4L_1)$

$f_2 = \frac{2v}{2L_2} = \frac{v}{L_2}$

$f_1 = \frac{V}{4L_1}$

$f_1 = f_2$

$\frac{v}{4L_1} = \frac{v}{L_2} \Rightarrow L_2 = 4L_1$

$60 = 4 \times L_1$

$L_1 = 15$ cm

54. [6] As, $f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$

$\Rightarrow f_1 = \frac{1}{2}\sqrt{\frac{6}{\mu}}$ and $f_2 = \frac{1}{2}\sqrt{\frac{54}{\mu}}$

$\Rightarrow \frac{f_1}{f_2} = \frac{1}{3}$ $[f_2 - f_1 = 12]$

$\therefore f_1 = 6$HZ

55. [16] We have given that the closed and an open organ pipe have same lengths.
For closed organ pipe

$f_c = (2n+1)\frac{v}{4\ell} = \frac{15v}{4\ell}$

For open organ pipe

$f_o = (n+1)\frac{v}{2\ell} = \frac{8v}{2\ell}$

the ratio of frequencies of their seventh overtones,

$\frac{f_c}{f_o} = \frac{15}{16} = \frac{a-1}{a}$

$\Rightarrow a = 16$

56. [1] Frequency of closed organ pipe

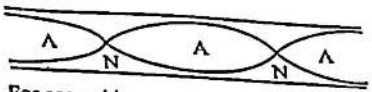
$f_n = \frac{nv}{4l}$

For 5th harmonic,

$f_5 = \frac{5V}{4\ell} \Rightarrow 405 = \frac{5 \times 324}{4\ell}$

$\Rightarrow \ell = 1m$

57. [900]



For second harmonic of open organ pipe
$L = \lambda$
So frequency

$f = \frac{V}{\lambda} = \frac{V}{L} = \frac{360}{40 \times 10^{-2}} = 900\,Hz$

58. [104] $400 = \frac{v}{4(L_1 + e)}$ ...(I)

$400 = \frac{5v}{4(L_2 + e)}$ ...(II)

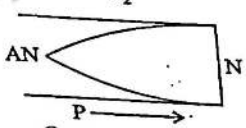
$\Rightarrow L_1 + e = \frac{\lambda}{4} = 21$ cm

$\Rightarrow L_2 + e = \frac{5\lambda}{4} = 105$ cm

$\Rightarrow e = 1$ cm & $L_2 = 104$ cm

59. [80] First overtone frequency of open organ pipe, $f_1 = \frac{2v}{2l_1}$

Fundamental frequency of closed organ pipe, $f_2 = \frac{v}{4l_2}$



Open organ pipe

According to question $f_1 = f_2$

$\frac{2v}{2l_1} = \frac{v}{4l_1} \Rightarrow l_1 = 4l_2 = 80$ cm

60. [50] We know that, $\lambda = \frac{v}{f} = \frac{340}{340} = 1$ m

First resonating length, $\lambda_1 = \frac{\lambda}{4} = 25$ cm

Second resonating length,

$\lambda_2 = \frac{3\lambda}{4} = 75$ cm

Third resonating length,

$\lambda_3 = \frac{5\lambda}{4} = 125$ cm

Height of water required $= \lambda 3 - \lambda 2 = 125 - 75 = 50$ cm

61. (d) After filling (fork A) frequency increases slightly.
So, initial frequenly of A,
$f_A = 340 - 5 \approx 335$ Hz

62. [4] Both piper vibrate in first overtone.

$f_c = f_o \Rightarrow \frac{3V_c}{4L} = \frac{2V_o}{2l_o} \Rightarrow \frac{3V_c}{4L} = \frac{V_o}{I_o}$

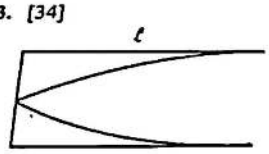
@FAKE_CBSE_YOGRAJ_EDUNET

$$\therefore \frac{V_s}{V_c}=\frac{3l_s}{4L}$$

Also, $\frac{V_s}{V_c}=\sqrt{\frac{\rho_1}{\rho_2}}$

Then, $\sqrt{\frac{\rho_1}{\rho_2}}=\frac{3l_0}{4L}\Rightarrow l_0=\frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$

63. [34]



We know that,

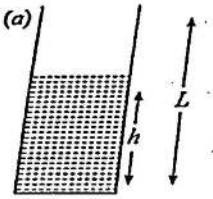
$\frac{\lambda}{4}=\ell\Rightarrow\lambda=4\ell$

$f=\frac{v}{\lambda}=\frac{v}{4\ell}\Rightarrow\ell=\frac{v}{4f}$

$\ell=\frac{34}{4\times25}=0.34\text{m}=34\text{cm}$

Hence, $\ell=34$ cm is the correct answer.

64. (a)



$L-h_1=n\frac{\lambda}{2}+\frac{\lambda}{4}$

$L-h_2=(n-1)\frac{\lambda}{2}+\frac{\lambda}{4}$

$\Rightarrow\frac{\lambda}{2}=h_2-h_1=24.5-17.0=7.5$ cm

$\Rightarrow\lambda=15$ cm

$v=f\lambda$

$f=2200$ Hz

65. [106] $V=\sqrt{\frac{B}{\rho}}$

$\frac{V_{pipe}}{V_{air}}=\frac{\sqrt{\frac{B}{2\rho}}}{\sqrt{\frac{B}{\rho}}}=\frac{1}{\sqrt{2}}$

$V_{pipe}=\frac{V_{air}}{\sqrt{2}}$

$f_n=\frac{(n+1)V_{pipe}}{2\ell}$

$f_1-f_0=\frac{V_{pipe}}{2\ell}=\frac{300}{2\sqrt{2}}$

$=106.05$ Hz ($\sqrt{2}=1.414$)

66. [0.62 to 0.63]

$f\propto\frac{1}{\ell_1}\Rightarrow f=\frac{k}{\ell_1}$ ...(i)

($\ell_1\Rightarrow$ initial length of pipe)

$\left(\frac{V}{V-V_T}\right)f=\frac{k}{\ell_2}$ ...(ii)

{V_T speed of tuning fork, $\ell_2\rightarrow$ new length of pipe}

(I) + (II)

$\frac{V-V_T}{V}=\frac{\ell_2}{\ell_1}$

$\frac{\ell_2}{\ell_1}-1=\frac{V-V_T}{V}-1$

$\frac{\ell_2-\ell_1}{\ell_1}=\frac{V_T}{V}$

$\frac{\ell_2-\ell_1}{\ell_1}\times100=\frac{-2}{320}\times100=-0.625$

67. (c) For resonance tube experiment, the speed of sound (v),

$v=2f(l_2-l_1)$

$v=2\times480\times(70-30)\times10^{-2}$

$v=960\times40\times10^{-2}$

$v=384$ m/s

68. (c) Fundamental frequency = 1.5 kHz

Highest frequency = 20000 Hz = 20 kHz

Now, $\frac{20\text{ kHz}}{1.5\text{ kHz}}=13.33$

∴ Possible hormones are 1, 3, 5, 7, 9, 11, 13 i.e., 7

JEE-Advanced

1. (b, c, d) Displacement is given by,

$Y(x,t)=\frac{0.8}{[(4x+5t)^2+5]}$

Now, for maximum displacement, $[(4x+5t)^2+5]$ should be minimum.

I.e. $(4x+5t)^2=0$ (as denominator cannot be zero)

So, $Y(x,t)=\frac{0.8}{5}=0.16\text{m}$

So, option (c) is correct.

We can differentiate the displacement equation and write it as follows:

$\frac{d^2y(x,t)}{dt^2}=c^2\frac{d^2y(x,t)}{dx^2}$ ...(i)

Now, $\frac{d^2y(x,t)}{dt^2}=\frac{160(4x+5t)^2}{\left[(4x+5t)^2+5\right]^3}-\frac{40}{\left[(4x+5t)^2+5\right]^3}$

$=25\left[\frac{6.4(4x+5t)^2}{\left[(4x+5t)^2+5\right]^3}-\frac{1.6}{\left[(4x+5t)^2+5\right]^3}\right]$

Similarly, $\frac{d^2y(x,t)}{dx^2}$

$=16\left[\frac{6.4(4x+5t)^2}{\left[(4x+5t)^2+5\right]^3}-\frac{1.6}{\left[(4x+5t)^2+5\right]^3}\right]$

Putting these values in equation (i), we get

$c=\sqrt{\frac{25}{16}}=\frac{5}{4}$ m/s

So, in 2 seconds, the wave would travel a distance of, $x=2c=2.5$ m/s

So, option (b) is also correct.

Also, since $y(x)=y(-x)$

Therefore, option (d) is also correct.

2. (a, b, c, d) Electric fields and magnetic fields are in light. Light is a transverse wave.

Then, sound travels as pressure difference, sound is a longitudinal wave.

Also, $y=f(x,t)$ has x and t variable, hence it represents displacement.

3. (a, c, d) A plane wave travels with constant intensity.

Whereas, intensity of a spherical wave decreases because the power in the wave is carried and constant at all radius. Intensity is power distributed over the spherical surface area.

$I=\frac{P}{4\pi r^2}$

For a cylindrical wave, the power is the same at all distances from the source. The power is distributed over the entire surface area.

$I=\frac{P}{2\pi rl}$

4. [5] Resultant amplitude,

$A=\sqrt{A_1^2+A_2^2+2A_1A_2\cos\theta}$

$\Rightarrow A=\sqrt{4^2+3^2+\left(2\times4\times3\times\cos\frac{\pi}{2}\right)}=5\text{m}$

JEE_CBSE_AIIMS_RAJ_EDUNET

$v = 300$ m/s
$f = 25$ Hz
Thus, $\lambda = \frac{v}{f} = \frac{300\text{ m/s}}{25\text{ Hz}} = 12\text{ m}$.

For a path difference of λ, the phase difference is 2π rad.
And, for a path difference of 6 m, the phase difference is:
$\frac{2\pi \times 6}{\lambda} = \frac{2\pi \times 6}{12} = \pi$ rad

The amplitude is the same at both points, hence, the amplitude difference is zero.

6. $y(x, t) = A\sin(kx - \omega t)$
$= A\sin\left(\frac{2\pi x}{\lambda} - 2\pi f t\right)$

Now, $v(x,t) = \frac{dy}{dt} = -A\omega\cos(kx - \omega t)$

Therefore, velocity amplitude $= v_{max} = A\omega$

And, $a(x,t) = \frac{dv}{dt} = -A\omega^2\sin(kx - \omega t)$

Therefore, acceleration amplitude $= a_{max} = A\omega^2$

7. (a) In a transverse wave, the particle displacement and particle velocity are perpendicular to the direction of propagation of the wave. Thus, options (c) and (d) are wrong.
since particle velocity = –wave velocity × slope
We know that,
$v_P = \omega\sqrt{A^2 - y^2} = 2\pi f\sqrt{A^2 - y^2}$
$= 2\pi\frac{c}{\lambda}\sqrt{A^2 - y^2}$
So,
$v_P = 2\pi\frac{0.1}{0.5}\sqrt{0.1^2 - 0.05^2} = \frac{\sqrt{3}\pi}{50}\hat{j}$ m/s

8. (c) We know that, $P = \frac{1}{2}\mu\omega^2A^2v$
Now, power is defined as energy per unit time,
$E \propto \omega^2A^2v$
Thus,
$E_1 \propto \omega^2A^2\left(\frac{L\omega}{\pi}\right)$ and $E_2 \propto (2\omega)^2A^2\left(\frac{L\omega}{\pi}\right)$
Therefore, $E_2 = 4E_1$

9. (a) We know that, $y = A\sin(kx - \omega t)$
So, $v = \frac{dy}{dt} = -A\omega\cos(kx - \omega t)$
So, maximum particle velocity is when $\cos(kx - \omega t) = -1$.
Thus, maximum particle velocity is $v = A\omega$

10. (a) Velocity of wave, $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{kx}{\mu}}$
Thus,
$\frac{v_2}{v} = \sqrt{\frac{1.5x}{x}} \Rightarrow \frac{v_2}{v} = \sqrt{1.5} = 1.22$
So, $v_2 = 1.22v$

11. (b) We know that, wave velocity, $v = \lambda f$
And, maximum particle velocity,
$v_{(max)P} = A\omega = 2\pi f y_0$
Given, $v_{(max)P} = 4v \Rightarrow 2\pi f y_0 = 4\lambda f$
Thus, $\lambda = \frac{\pi y_0}{2}$

12. (a, c)
$y(x,t) = A\sin(kx - \omega t) = 10^{-3}\sin\left(\frac{2\pi x}{\lambda} - 2\pi f t\right)$
Now,
$v(x,t) = \frac{dy}{dt} = -2\pi f 10^{-3}\sin\left(\frac{2\pi x}{\lambda} - 2\pi f t\right)$
So, maximum velocity, $v_{max} = 2\pi f 10^{-3}$
This is given as, $v_{max} = \frac{v}{10}$
Hence, $2\pi f 10^{-3} = \frac{v}{10}$
We get $f = \frac{10^3}{2\pi}$ Hz
So, option (c) is correct.
Now, $\lambda = \frac{v}{f} = \frac{10}{\left(\frac{10^3}{2\pi}\right)} = 2\pi \times 10^{-2}$ m

13. (b, c) $\omega = 15\pi$, $k = 10\pi$ (SI units)
Speed of wave, $v = \frac{\omega}{k} = 1.5$ m/s.
Wavelength of wave $\lambda = \frac{2\pi}{k} = \frac{2\pi}{10\pi} = 0.2$ m
$10\pi x$ and $15\pi t$ have the same sign. Therefore, wave is travelling in negative x-direction.
∴ Correct options are (b) and (c).

14. (a, b, c, d) $y(x, t) = A\sin(kx - \omega t) = 10^{-4}\sin(60t + 2x)$
On comparing, we get that $A = 10^{-4}$ m
And, $k = \frac{2\pi}{\lambda} = 2 \Rightarrow \lambda = \pi m$
Now, $\omega = 2\pi f = 60 \Rightarrow f = \frac{30}{\pi}$ Hz
And, $v = \lambda f = \pi\frac{30}{\pi} = 30$ m/s

15. [3] Let the amplitude of each wave is A.
The ones having phases of 0 and π will cancel each other.
Resultant of other two is having angle $\frac{\pi}{3}$ between them is $2A\cos\frac{\pi}{6} = \sqrt{3}A$
Intensity $I \propto A^2 = 3A^2$
Thus, $n = 3$.

16. [0.5] Here, $y = \frac{1}{(1+x)^2}$ at time $t = 0$
And, $y = \frac{1}{[1+(x-1)^2]}$ at $t = 2$s
It is given that the shape of propagation does not change, and according to mathematics, if $f(x) = f(x-1)$, it means the shape of the graph is the same, and just the position shifts in the right direction by 1 unit.
Here, wave moves 1 m in 2 sec, so,
velocity of wave $= \frac{x}{t} = \frac{1\text{m}}{2\text{s}} = 0.5$ m/s
Hence, the velocity of wave is 0.5 m/s.

17. [0.12] At the lowest point, $T_1 = m_1 g = 2g$
At the top point, $T_2 = (m_1 + m_2)g = 8g$
And, we know that, $v = \lambda f = \sqrt{\frac{T}{\mu}}$
On rearranging, $\frac{\sqrt{T}}{\lambda} = f\sqrt{\mu} =$ constant
Therefore, $\frac{\sqrt{T_1}}{\lambda_1} = \frac{\sqrt{T_2}}{\lambda_2} \Rightarrow \frac{\sqrt{2g}}{0.06} = \frac{\sqrt{8g}}{\lambda_2}$
Thus, $\lambda_2 = 0.12$ m

18. Let $y = A\sin(\omega t \pm kx + \phi)$
$\left(\frac{dy}{dt}\right)_{max} = \omega A$ and $\left(\frac{d^2y}{dt^2}\right)_{max} = \omega^2 A$
Hence, $\frac{\omega^2 A}{\omega A} = \omega = 30$ rad s^{-1}
$A = 0.1$ m
wave velocity $v = \frac{\omega}{k} = 20$ m/s
$\Rightarrow k = \frac{3}{2}$ m^{-1}
Thus, wave form is
$y = 0.1\sin\left(30t \pm \frac{3x}{2} + \phi\right)$

19. (b) The pulses overlap each other completely after 2 s, and due to this, the string is straight and does not have any potential energy. Thus, its entire energy must be kinetic energy.

20. (b) Velocity of wave,
$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{T}{(M/L)}}$
$= \sqrt{\frac{1.6\text{N}}{(10^{-2}\text{ kg}/0.4\text{ m})}} = 8$ m/s
And, distance traveled by the wave,
$d = 2L = 2(0.4\text{ m}) = 0.8$ m
Thus, $\Delta t = \frac{d}{v} = \frac{0.8\,m}{8\,m/s} = 0.1s$

21. (b) $y = 4\cos^2\left(\frac{1}{2}t\right)\sin(1000t)$
$y = 2(1 + \cos t)\sin(1000t)$

@FAKE_CRSE Y @RAJ_EDUNET

$y = 2\sin(1000t) + (2\cos t)\sin(1000t)$
$y = 2\sin(1000t) + 2\sin(1001t) + 2\sin(999t)$
$y = y_1 + y_2 + y_3$
Thus, three different waves would be superimposed.

22. (a) We can write,
$y_1 = A\sin(2\pi\omega_1 t)$ and $y_2 = A\sin(2\pi\omega_2 t)$
So, $y = y_1 + y_2 = A\sin(2\pi\omega_1 t) + A\sin(2\pi\omega_2 t)$

$$y = 2A\sin 2\pi\frac{(\omega_1+\omega_2)}{2}t\cos 2\pi\frac{(\omega_1-\omega_2)}{2}t$$

Thus,
Amplitude, $A' = 2A\cos\pi(\omega_2-\omega_1)t$
Also,
$I \propto (A')^2 = 4A^2\cos^2\pi(\omega_2-\omega_1)t$
For I to be maximum, $\cos\pi(\omega_2-\omega_1)t = \pm 1$
So, $\pi(\omega_2-\omega_1)t = 0, \pi, 2\pi, \ldots$

$$\text{Thus, } T = t_2 - t_1 = \frac{1}{\omega_2-\omega_1} = 10^{-3}\,s$$

(b) For intensity $2A^2$, the amplitude would be $\pm\sqrt{2}A$.

$$\text{Thus, } 2A\cos(\omega_2-\omega_1)\frac{t}{2} = \pm\sqrt{2}A$$

$$\text{Thus, } \cos(\omega_2-\omega_1)\frac{t}{2} = \pm\frac{1}{\sqrt{2}}$$

So,

$$(\omega_2-\omega_1)\frac{t_1}{2} = \frac{\pi}{4}, \quad (\omega_2-\omega_1)\frac{t_2}{2} = \frac{3\pi}{4}$$

Thus, cosine function decreases in the interval $\frac{\pi}{4}$ to $\frac{3\pi}{4}$:

$$t_1 = \frac{\pi}{2(\omega_2-\omega_1)} = \frac{1}{4(\nu_2-\nu_1)}$$

$$t_2 = \frac{3\pi}{2(\omega_2-\omega_1)} = \frac{3}{4(\nu_2-\nu_1)}$$

So, time interval,

$$T = t_2 - t_1 = \frac{1}{2(\nu_2-\nu_1)} = 5\times10^{-3}\,s$$

During this time interval the detector remains idle for each cycle of the intensity of the signal.

23. (a) We know that,

$$f \propto v \propto \sqrt{T}$$

It is given that,
$f_{AB} = 2f_{CD} \Rightarrow T_{AB} = 4T_{CD}$
Since, net force = 0
$\Rightarrow T_{AB}\times x = T_{CD}\times(l-x)$
$\Rightarrow 4T_{CD}\times x = T_{CD}\times(l-x)$
$\Rightarrow 4x = (l-x)$

$$\text{So, } x = \frac{l}{5}$$

24. (a) We know that;

$$f = \frac{n}{2L}\sqrt{\frac{T}{m}} = \frac{n}{2L}\sqrt{\frac{Mg}{m}}$$

For $n = 5$,

$$f_1 = \frac{5}{2L}\sqrt{\frac{9g}{m}}$$

Now, for $n = 3$,

$$f_2 = \frac{3}{2L}\sqrt{\frac{Mg}{m}}$$

Since, $f_1 = f_2$

$$\frac{5}{2L}\sqrt{\frac{9g}{m}} = \frac{3}{2L}\sqrt{\frac{Mg}{m}}$$

Thus, we get,
$M = 25$ kg

25. (a) In air, $T = mg = \rho Vg$

$$\text{And, } \nu = \frac{1}{2L}\sqrt{\frac{T}{\mu}} = \frac{1}{2L}\sqrt{\frac{\rho Vg}{\mu}}$$

When it is half immersed in water,
$T' = mg - \text{upthrust}$

$$= \frac{V}{2}g(2\rho-\rho_w)$$

So, the new frequency becomes,

$$\nu' = \frac{1}{2L}\sqrt{\frac{\frac{V}{2}g(2\rho-\rho_w)}{\mu}}$$

Therefore,

$$\frac{\nu'}{\nu} = \sqrt{\frac{\frac{V}{2}g(2\rho-\rho_w)}{\rho Vg}} = \sqrt{\frac{(2\rho-\rho_w)}{2\rho}}$$

So,

$$\nu' = \nu\sqrt{\frac{(2\rho-\rho_w)}{2\rho}} = 300\sqrt{\frac{(2\rho-1)}{2\rho}}\,\text{Hz}$$

26. (c) To form a stationary wave with $y = a\cos(kx-\omega t)$, the wave should be in the opposite direction of this wave and amplitude should be negative (i.e. the phase difference should be of π)
$y = a\cos(kx+\omega t+\pi) = -a\cos(kx+\omega t)$

27. (a, c, d) The fixed end of the string is a node, and the free end is an antinode.
Therefore, $x = 0$ represents a node, and $x = 3$ m represents an antinode.
Possible modes of vibration are

$$L = (2n+1)\frac{\lambda}{4} \quad \text{where } n = 0, 1, 2, 3, \ldots\ldots$$

$$\text{So, } \lambda = \frac{4L}{(2n+1)} = \frac{4\times3}{(2n+1)} = \frac{12}{(2n+1)}$$

We can further find,

$$k = \frac{2\pi}{\lambda} = \frac{2\pi(2n+1)}{12} = \frac{\pi(2n+1)}{6}$$

Now,

$$\omega = vk = 100\frac{\pi(2n+1)}{6} = 50\frac{\pi(2n+1)}{3}$$

We find λ, ω and k, for $n = 0, 1, 2, \ldots\ldots$

For $n = 0$, $y(t) = A\sin\frac{\pi x}{6}\cos\frac{50\pi t}{3}$

For $n = 2$, $y(t) = A\sin\frac{5\pi x}{6}\cos\frac{250\pi t}{3}$

For $n = 7$, $y(t) = A\sin\frac{5\pi x}{2}\cos 250\pi t$

28. (a, b, c) This is because standing waves can only be produced only when similar waves are traveling in opposite directions.

29. (b, c) The boundary condition of the waves must be satisfied, which basically means that the waves must have zero displacement at the corners and boundaries of the plates. Hence, the function representing the wave must have zero value at the given coordinates of the corners.
In options (b) and (c),
$u(x, y) = 0$ for $x = 0, y = 0, x = L$, and $y = L$

30. [5] $f = \frac{n}{2\ell}\sqrt{\frac{T}{\mu}}$

Successive harmonics are $f_{(n)}$ and $f_{(n+1)}$

$$f_{(n)} = \frac{n}{2}\sqrt{\frac{T}{\mu}} = 750 \quad \ldots(i)$$

$$f_{(n+1)} = \frac{n+1}{2}\sqrt{\frac{T}{\mu}} = 1000 \quad \ldots(ii)$$

$\because f_{(n+1)} - f_{(n)} = 1000 - 750 = 250$ Hz

$$\therefore \frac{n+1}{2}\sqrt{\frac{T}{\mu}} - \frac{n}{2}\sqrt{\frac{T}{\mu}} = 250$$

$$\Rightarrow \sqrt{\frac{T}{\mu}} = 500$$

$\Rightarrow T = (500)^2\mu \Rightarrow T = (500)^2(2\times10^{-2})$
$\Rightarrow T = 5$N

31. [11] Coefficient of linear expansion,

$$\alpha = \frac{\Delta l}{l\times\Delta T}$$

Strain $= \alpha\Delta T$
Stress $= Y\times$ strain $= Y\alpha\Delta T$
Tension, $T = YA = Y\alpha\Delta T\pi r^2$
Velocity, $v = \sqrt{\frac{T}{m}}$

$$n = \frac{1}{2L}v = \frac{1}{2L}\sqrt{\frac{T}{m}}$$

$$= \frac{1}{2L}\sqrt{\frac{Y\alpha\Delta T\pi r^2}{m}} = 11\,\text{Hz}$$

@FAKE_CBSE_X@RAJ_EDUNET

32. We know that,

$$\lambda = \frac{v}{f} = \frac{330\,\text{m/s}}{660\,\text{Hz}} = 0.5\,\text{m}$$

Amplitude is maximum at the first antinode of the wave which is situated at a distance of $\frac{\lambda}{4} = 0.125\,\text{m}$ away from the wall.

33. For a stationary wave: $y = a \sin(kx) \cos(\omega t)$

Where $k = \frac{2\pi}{\lambda} = \frac{2\pi}{2L} = \frac{\pi}{L}$

Now, maximum amplitude is given as, $A = a \sin kx$

Mass of dx length of the string, $dm = \mu dx$

We are supposed to calculate the total energy stored in the string.

For that, we can find

$$dE = \frac{1}{2}(dm)v^2 = \frac{1}{2}(\mu dx)\omega^2 A^2$$

$$= \frac{\mu\omega^2}{2}(a\sin kx)^2\,dx$$

So, $E = \int_0^L \frac{\mu\omega^2}{2}(a\sin kx)^2\,dx = \frac{1}{4}\mu a^2\omega^2 L$

We know that,

$$\omega = 2\pi f = 2\pi\frac{v}{\lambda} = 2\pi\frac{\sqrt{\frac{T}{\mu}}}{2L} = \frac{\pi}{L}\sqrt{\frac{T}{\mu}}$$

We can put this in E and get:

$$E = \frac{\pi^2 a^2 T}{4L}$$

34. (a) We know that,

$$\mu = \frac{M}{L} \quad \text{and} \quad v = \sqrt{\frac{T}{\mu}}$$

So, $\mu_1 = \frac{0.06\,\text{kg}}{4.8\,\text{m}} = 0.0125\,\text{kg/m}$

$$\Rightarrow v_1 = \sqrt{\frac{80\,\text{N}}{0.0125\,\text{kg/m}}} = 80\,\text{m/s}$$

$$\mu_2 = \frac{0.2\,\text{kg}}{2.56\,\text{m}} = 0.0781\,\text{kg/m}$$

$$\Rightarrow v_2 = \sqrt{\frac{80\,\text{N}}{0.0781\,\text{kg/m}}} = 32\,\text{m/s}$$

Therefore,

$$\text{Total time, } t = \frac{4.8\,\text{m}}{80\,\text{m/s}} + \frac{2.56\,\text{m}}{32\,\text{m/s}} = 0.14\,\text{s}$$

(b) Now,

R_a = Reflection amplitude coefficient

$$= \frac{\sqrt{\mu_1} - \sqrt{\mu_2}}{\sqrt{\mu_1} + \sqrt{\mu_2}} = -0.40$$

Thus, reflected amplitude

$= 3.5 \times 10^{-2} \times 0.40 = 1.4 \times 10^{-2}$ m

T_a = Transmission amplitude coefficient

$$= \frac{2\sqrt{\mu_1}}{\sqrt{\mu_1} + \sqrt{\mu_2}} = 0.60$$

Thus, transmitted amplitude

$= 3.5 \times 10^{-2} \times 0.60 = 2.1 \times 10^{-2}$ m

35. (a) Wave length, $\lambda = \frac{2\pi}{k} = \frac{2\pi}{A}$

Frequency of wave $n = \frac{\omega}{2\pi} = \frac{b}{2\pi}$

(b) Let the intensity of first wave is I, therefore, intensity of second wave will be $0.64I$,

Now, we have $I \propto A^2$

Hence, $\frac{I_2}{I_1} = \frac{A_2^2}{A_1^2} = 0.64$

So, $A_2 = 0.8\,A_1 = 0.8A$

Thus, equation of reflection becomes:

$y_2 = 0.8A\cos(bt - ax)$

(c) Therefore, particle velocity,

$$v = \frac{dy_2}{dt} = -0.8Ab\sin(bt - ax)$$

So, maximum velocity, $v_{max} = 0.8Ab$

And, minimum velocity, $v_{min} = 0$

(d) Now, equation of resulting wave,

$y = y_1 + y_2 = A\cos(ax + bt) - 0.8\,A\cos(bt - ax)$

$y = A\cos(ax + bt) - (A - 0.2A)\cos(bt - ax)$

$y = A\cos(ax + bt) - A\cos(bt - ax) + 0.2A\cos(bt - ax)$

$$y = 2A\sin\frac{(ax + bt + bt - ax)}{2}\sin\frac{(bt - ax - ax - bt)}{2} + 0.2A\cos(bt - ax)$$

$y = -2A\sin(ax)\sin(bt) + 0.2A\cos(bt - ax)$

Now, position of antinodes:

$$ax = (2n+1)\frac{\pi}{2},\ n = 0, 1, 2, \ldots$$

Or, $x = (2n+1)\frac{\pi}{2a} = \frac{\pi}{2a}, \frac{3\pi}{2a}, \frac{5\pi}{2a}, \ldots$

The traveling wave is moving along the x-axis.

36. (a) For standing waves, the two waves must travel from opposite directions.

Thus, these waves are:

$z_1 = A\cos(kx - \omega t)$

$z_2 = A\cos(kx + \omega t)$

So, resulting wave:

$z = z_1 + z_2 = A\cos(kx - \omega t) + A\cos(kx + \omega t)$

$z = 2A\cos(kx)\cos(\omega t) = R\cos(\omega t)$

Where, $R = 2A\cos(kx)$

Intensity of the resulting wave, $I = 4A^2\cos^2(kx)$

Intensity is zero when,

$kx = (2n+1)\frac{\pi}{2}$ for $n = 0, 1, 2, \ldots$

So, $x = (2n+1)\frac{\pi}{2k}$ for $n = 0, 1, 2, \ldots$

(b) For a wave propagating in a direction making an angle 45° with positive x and positive y-axis, the component waves must be of equal amplitude.

Thus, these waves are:

$z_1 = A\cos(kx - \omega t)$

$z_2 = A\cos(ky - \omega t)$

So, resulting wave:

$z = z_1 + z_2 = A\cos(kx - \omega t) + A\cos(ky - \omega t)$

$$z = 2A\cos\left(\frac{k(x-y)}{2}\right)\cos\left(\frac{k(x+y)}{2} - \omega t\right)$$

$$= R\cos\left(\frac{k(x+y)}{2} - \omega t\right)$$

Where, $R = 2A\cos\left(\frac{k(x-y)}{2}\right)$

Intensity of the resulting wave,

$$I = 4A^2\cos^2\left(\frac{k(x-y)}{2}\right)$$

Intensity is zero when,

$$\frac{k(x-y)}{2} = (2n+1)\frac{\pi}{2} \text{ for } n = 0, 1, 2, \ldots$$

37. (a) We know that,

Speed of sound,

$$v = \frac{\omega}{k} = \frac{100\pi}{0.5\pi} = 200\,\text{m/s}$$

38. (b) Since, $v = \sqrt{\frac{\gamma RT}{M}}$

So, $v \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$

39. (c) Since, $v = \sqrt{\frac{\gamma RT}{M}}$

So, $\frac{v_{N_2}}{v_{He}} = \frac{\sqrt{\frac{(7/5)RT}{14}}}{\sqrt{\frac{(5/3)RT}{4}}} = \frac{\sqrt{3}}{5}$

40. (a, b, c) Let n_1 be the harmonic corresponding to 50.7 cm & n_2 the harmonic corresponding to 83.9 cm.

Now, $\frac{\lambda}{2} = (83.9 - 50.7)\,\text{cm} = 33.2\,\text{cm}$

Therefore, $\lambda = 66.4$ cm

Thus, option (c) is correct.

@FAKE_CBSE_@RAJ_EDUNET

The length corresponding to the fundamental mode should be approximately close to

$\frac{\lambda}{4} = 16.6\text{cm}$

Furthermore, 50.7 cm must be an odd multiple of it.

Since, 16.6 cm × 3 = 49.8 cm ≈ 50.7 cm, therefore, it is the 3rd harmonic.

Now, $e + 50.7\text{cm} = \frac{3\lambda}{4} = 49.8\text{cm}$

So, $e = -0.9$ cm

Therefore, the end correction of this experiment is 0.9 cm.

Hence, option (*b*) is also correct.

Speed of sound, $v = \lambda f$

$= 0.664\text{ m} \times 500\text{ Hz} = 332\text{ m/s}$

41. $I \propto \frac{1}{r^2}$ (in case of point source) and $I \propto A^2$

$\Rightarrow A \propto \frac{1}{r}$ or $\frac{A_1}{A_2} = \frac{r_2}{r_1} = \frac{25}{9}$

42. [False] $v_{\text{sound}} = \sqrt{\frac{\gamma RT}{M}}$

$\Rightarrow \frac{v_{H_2}}{v_{He}} = \frac{\sqrt{\gamma_{H_2}/M_{H_2}}}{\sqrt{\gamma_{He}/M_{He}}}$

$= \frac{\sqrt{(7/5)/2}}{(5/3)/4} = \sqrt{\frac{42}{25}}$

43. (*b*) (1) $f_0 = \frac{1}{2L_0}\sqrt{\frac{T_0}{\mu}}$

(2) $f_1 = \frac{1}{2L_0}\sqrt{\frac{T_0}{2\mu}}$

(3) $f_2 = \frac{1}{2L_0}\sqrt{\frac{T_0}{3\mu}}$

(4) $f_3 = \frac{1}{2L_0}\sqrt{\frac{T_0}{4\mu}}$

For all highest fundamental is when length is L_0.

44. (*b*) (1) $f_0 = \frac{1}{2L_0}\times\sqrt{\frac{T_1}{\mu}} = \frac{1}{2L}\sqrt{\frac{T_0}{\mu}}$

(2) $f_0 = \frac{3\times2}{2\times3L_0}\sqrt{\frac{T_2}{2\mu}} \Rightarrow T_2 = \frac{T_0}{2}$

(3) $f_0 = \frac{5\times2}{5L_0}\sqrt{\frac{T_3}{3\mu}} \Rightarrow T_3 = \frac{3T_0}{16}$

(4) $f_0 = \frac{14\times4}{2\times7L_0}\sqrt{\frac{T_4}{4\mu}} \Rightarrow T_4 = \frac{T_0}{16}$

45. [True] According to Snell's law,

$\frac{\sin i}{\sin r} = \frac{v_a}{v_w} = \frac{330}{1500} = 0.22$

For refraction into water, maximum value of $r = 90°$

$\sin r = \sin 90° = 1$

Or, $(\sin r)_{max} = 0.22$

Or, $I_{max} = \sin^{-1}(0.22) = 13°$

If Snell's law is applicable to sound waves, then, with just the right angle of incidence and velocity, it can refract into the water away from the normal. But as the given value of $i = 60° > I_{max}$, therefore, sound will not be refracted into water, but it will be reflected back into air.

46. (*d*) We know that, $l = \frac{\lambda}{4}$ or $\lambda = 4l$

So, $v = \lambda f = 4lf = 4 \times 244 \times l$

Now, when $l = 0.350 + 0.005 = 0.355$ m, then, $v = 4 \times 244 \times 0.355 = 346.5$ m/s

When $l = 0.350 - 0.005 = 0.345$ m, then, $v = 4 \times 244 \times 0.345 = 336.5$ m/s

So, velocity is in the range 336.5 m/s and 346.5 m/s.

We also know that,

$v = \sqrt{\frac{\gamma RT}{M \times 10^{-3}}} = \sqrt{100\gamma RT}\sqrt{\frac{10}{M}}$

(where molar mass is given in grams)

On putting all the values from the question, we get that,

$v_{Ne} = \sqrt{100\times1.67\times RT}\sqrt{\frac{10}{20}}$

$= 640\times\frac{7}{10} = 448\text{ m/s}$

$v_{Ar} = \sqrt{100\times1.67\times RT}\sqrt{\frac{10}{36}}$

$= 640\times\frac{17}{32} = 340\text{ m/s}$

$v_{O_2} = \sqrt{100\times1.4\times RT}\sqrt{\frac{10}{32}}$

$= 640\times\frac{9}{16} = 331.8\text{ m/s}$

$v_{N_2} = \sqrt{100\times1.4\times RT}\sqrt{\frac{10}{28}}$

$= 640\times\frac{3}{5} = 354\text{ m/s}$

47. (*b*) We can write,

$\lambda = \frac{v}{f} = \frac{336\text{m/s}}{512\text{Hz}} = 0.656\text{m} = 65.6\text{cm}$

Since, $\frac{\lambda}{4} = L + e$

$\frac{65.6}{4} = L + 0.6r = L + 1.2$

So, $L = 15.2$ cm

48. (*b*) Given,

fundamental frequency of pipe = frequency of 2nd harmonic of string

$\frac{v}{4L} = \frac{2}{2l}\sqrt{\frac{T}{\mu}}$

$\frac{320\text{m/s}}{4\times0.8\text{m}} = \frac{2}{2\times0.5\text{m}}\sqrt{\frac{50\text{N}}{\mu}}$

We get that,

$\mu = 0.02\text{ kg/m} = \frac{M}{l} = \frac{M}{0.5\text{m}}$

So, $M = 0.01$ kg $= 10$ g

49. (*a*) According to the question,

Frequency of tuning fork = 3rd harmonic of closed pipe + 4

$= 3\left(\frac{v}{4L}\right) + 4 = 3\left(\frac{340\text{m/s}}{4\times0.75}\right) + 4$

$= 344$ Hz

50. (*a*) We know that, $\omega = 2\pi f$

So, $f_1 = \frac{\omega_1}{2\pi} = \frac{100\pi}{2\pi} = 50\text{Hz}$

$f_2 = \frac{\omega_2}{2\pi} = \frac{92\pi}{2\pi} = 46\text{Hz}$

Therefore, number of beats heard $= f_1 - f_2 = 50 - 46 = 4$ Hz

Thus, number of times observers hear maximum intensity in one second = 4

51. (*d*) We can write the equations as follows:

$l_1 + e = \frac{v}{4f}$ and $l_2 + e = \frac{3v}{4f}$

So,

$l_2 - l_1 = \frac{2v}{4f} = \frac{\lambda}{2} = (63.2 - 30.7)\text{ cm}$

$= 32.5$ cm

Thus, $\lambda = 65.0\text{ cm} = 0.65$ m

Now, velocity of sound, $v = \lambda f$

$= 0.65\text{ m} \times 512\text{ Hz} = 332.8\text{ m/s}$

Therefore,

Error observed $= v - 330$ m/s

$= (332.8 - 330)\text{ m/s} = 2.8\text{ m/s}$

$= 280\text{ cm/s}$

52. (*b*) For open pipe, frequency of second harmonic, $f_1 = \frac{2v}{2L} = \frac{v}{L}$

For closed pipe, frequency of n^{th} harmonic, $f_2 = \frac{(2n-1)v}{4L} = \frac{(2n-1)f_1}{4}$ ...(i)

Put $n = 3$ in equation (*i*) we get:

$f_2 = \frac{(2\times3-1)f_1}{4} = \frac{5f_1}{4}$

Put $n = 5$ in equation (*i*) we get:

$f_2 = \frac{(2\times5-1)f_1}{4} = \frac{9f_1}{4}$

@AKE_CBSE × @RAJ EDUNET

53. (c) $f_{closed} = f_{open}$

$$\frac{3v_{closed}}{4L} = \frac{2v_{open}}{2l}$$

So, $\frac{v_{open}}{v_{closed}} = \frac{3l}{4L}$

We know that,

$v \propto \frac{1}{\sqrt{\rho}}$

$$\frac{v_{open}}{v_{closed}} = \sqrt{\frac{\rho_1}{\rho_2}}$$

So, $\sqrt{\frac{\rho_1}{\rho_2}} = \frac{3l}{4L}$

Therefore, $l = \frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$

54. (b) Let the end correction in a closed organ pipe be e

For fundamental frequency,

$$f_1 = \frac{v}{4(l_1 + e)} = \frac{v}{4(0.1 + e)}$$

For first overtone,

$$f_2 = \frac{3v}{4(l_2 + e)} = \frac{3v}{4(0.35 + e)}$$

According to the question,

$f_1 = f_2$

$$\frac{v}{4(0.1+e)} = \frac{3v}{4(0.35+e)}$$

So, $0.35 + e = 0.3 + 3e$

Thus, $e = 0.025$ m

55. (d) Let the density of material be ρ which is the same for both the wires.

Therefore, mass per unit lengths will be:

$$\mu_1 = \frac{\pi(2r)^2 L\rho}{L} = 4\pi r^2\rho$$

$$\mu_2 = \frac{\pi(r)^2 2L\rho}{2L} = \pi r^2\rho$$

Velocity of transverse wave in a stretched string with tension T and mass per unit length μ is given by:

$$v = \sqrt{\frac{T}{\mu}}$$

For the two wires, we have, $T_1 = T_2 = T$

$$v_1 = \sqrt{\frac{T}{\mu_1}} = \sqrt{\frac{T}{4\pi r^2\rho}}$$

$$v_2 = \sqrt{\frac{T}{\mu_2}} = \sqrt{\frac{T}{\pi r^2\rho}}$$

In the fundamental mode, the wavelength is twice the length of the wire.

$\lambda_1 = 2L$

$$\Rightarrow v_1 = \frac{v_1}{2L} = \frac{1}{2L}\sqrt{\frac{T}{4\pi r^2\rho}} = \frac{1}{4L}\sqrt{\frac{T}{\pi r^2\rho}}$$

$\lambda_2 = 4L$

$$\Rightarrow v_2 = \frac{v_2}{4L} = \frac{1}{4L}\sqrt{\frac{T}{\pi r^2\rho}}$$

Therefore, $v_1 = v_2$

Or, $\frac{v_1}{v_2} = 1$

56. (a) Fundamental frequency in an open organ pipe, $f_{1,o} = \frac{v}{2L}$

Frequency of 3rd harmonic in a closed organ pipe, $f_{3,c} = \frac{3v}{4L}$

Now,

$$f_{3,c} - f_{1,o} = \frac{3v}{4L} - \frac{v}{2L} = \frac{v}{4L} = 100\,\text{Hz}$$

Therefore, $\frac{v}{L} = 400\,\text{Hz}$

So,

Fundamental frequency of the open organ pipe, $f_{1,o} = \frac{v}{2L} = \frac{400}{2} = 200\,\text{Hz}$

57. (c) For closed pipe, frequency of 1th harmonic,

$$f_{1,c} = \frac{(2n-1)v}{4L_1} = \frac{v}{4L_1} \quad \ldots(i)$$

For open pipe, frequency of 3rd harmonic, $f_{3,o} = \frac{3v}{2L_2}$

But $f_{1,c} = f_{3,o}$

$$\frac{v}{4L_1} = \frac{3v}{2L_2}$$

Thus, $\frac{L_1}{L_2} = \frac{1}{6}$

58. (a) For closed pipe, fundamental frequency,

$$f_c = \frac{v}{4L} = 512\,\text{Hz}$$

Thus, $\frac{v}{L} = 2048$

Now, for an open pipe, fundamental frequency, $f_o = \frac{v}{2L} = \frac{2048}{2} = 1024\,\text{Hz}$

59. (c) For an open end pipe,

$$f = \frac{v}{2L}$$

When it is dipped in water, one end closes, making the pipe a closed pipe,

So, $f' = \frac{v}{4L'}$

We know that, $L' = \frac{L}{2}$

So, $f' = \frac{v}{4\left(\frac{L}{2}\right)} = \frac{v}{2L} = f$

60. (a, d) Larger the length of the air column, feebler is the intensity.

For closed pipe, fundamental frequency is given as:

$$f_o = \frac{v}{4(L+e)}$$

Where, $e = 0.6 \times$ radius of the tube

61. (a,b,c,d) On comparing, we see that

$k = 10\pi$ and $\omega = 50\pi$

$kx = \frac{\pi}{2}, \frac{3\pi}{2}, \ldots = 10\pi x$

Hence, node position,

$x = 0.05$ m, 0.15 m

Antinode is at $kx = \pi = 10\pi x$

Hence, antinode position,

$x = 0.1$ m

Also,

Speed of the wave, $v = \frac{\omega}{k} = \frac{50\pi}{10\pi} = 5\,\text{m/s}$

And, $\lambda = \frac{2\pi}{k} = \frac{2\pi}{10\pi} = 0.2\,\text{m}$

62. (a,b,d) $v = 320$ m/s and $L = 1$ m

Fundamental frequency,

$$f_0 = \frac{v}{4L} = \frac{320\,\text{m/s}}{4 \times 1\,\text{m}} = 80\,\text{Hz}$$

In closed pipes, higher order harmonics are odd integral multiples of the fundamental frequency,

So, $f = (2n-1)f_0$ where $n = 1, 2, 3, \ldots$.

So higher order frequencies are 240, 400, 560, ...

63. (a, c) We know that,

$$f = \frac{v}{4L}$$

So,

$$L = \frac{v}{4f} = \frac{330\,\text{m/s}}{4 \times 264\,\text{Hz}} = 0.3125\,\text{m} = 31.25\,\text{cm}$$

$(2n-1)l = 3 \times 31.25 = 93.75$cm

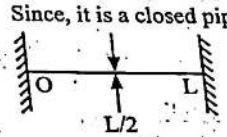
64. (b, c) $f_1 - f_2 = 6$ Hz; $T_1 > T_2$

To regain the beat frequency, we have to decrease T_1 or increase T_2.

65. (b, d) At open end phase of pressure wave changes by 180°. So, compression returns as rarefaction. At closed end there is no phase change. So, compression returns as compression and rarefaction as rarefaction.

66. (A - p, t; B - p, s; C - q, s; D - q, r)

Since, it is a closed pipe



$$\frac{\lambda}{4} = L \Rightarrow \lambda = 4L$$

@FREE_CBSE_X @RAJ_BOUNET

This is a longitudinal wave.
So, (A) matches with statements (p) and (t)
(B) Since, it is an open pipe

$$\frac{\lambda}{2}=L\Rightarrow\lambda=2L$$

This is a longitudinal wave.
So, (B) matches with statements (p) and (s).
(C) It this case also,

$$\frac{\lambda}{2}=L\Rightarrow\lambda=2L$$

This is a transverse wave.
So, (C) matches with statements (q) and (s).
(D) Here,

$$\frac{\lambda}{2}+\frac{\lambda}{2}=L\Rightarrow\lambda=L$$

This is a transverse wave.
So, (D) matches with statements (q) and (r).

67. [0.62 to 0.63]

$$f\propto\frac{1}{\ell_1}\Rightarrow f=\frac{k}{\ell_1} \quad ...(i)$$

($\ell_1\Rightarrow$ initial length of pipe)

$$\left(\frac{v}{v-v_T}\right)f=\frac{k}{\ell_2} \quad ...(ii)$$

{v_T speed of tuning fork, $\ell_1\rightarrow$ new length of pipe}

$(i)\div(ii)$

$$\frac{v-v_T}{v}=\frac{\ell_2}{\ell_1}$$

$$\frac{\ell_2}{\ell_1}-1=\frac{v-v_T}{v}-1$$

$$\frac{\ell_2-\ell_1}{\ell_1}=\frac{v_T}{v}$$

$$\frac{\ell_2-\ell_1}{\ell_1}\times100=\frac{-2}{320}\times100=-0.625$$

68. [5] We know that,

$$v=\sqrt{\frac{T}{\mu}}=\sqrt{\frac{TL}{M}}=\sqrt{\frac{(0.5N)(0.2m)}{(0.001kg)}}$$

$=10$ m/s

So, $\lambda=\frac{v}{f}=\frac{10m/s}{100Hz}=0.1\text{m}=10\text{cm}$

Therefore,
Separation between two node

$$=\frac{\lambda}{2}=5\text{cm}$$

69. [43] We know that, $f=\frac{v}{4L}=212.5\text{Hz}$

So, $L=\frac{340\text{m/s}}{4\times212.5\text{Hz}}=0.4\text{m}$

In a closed pipe, only odd harmonics are present.

Assume l_1, l_2, l_3, l_4, etc. to be the lengths corresponding to the 3rd harmonic, 5th harmonic, 7th harmonic, and the 9th harmonic.

So, $\frac{3v}{4l_1}=212.5\text{Hz}\Rightarrow l_1=1.2\text{m}$

$\frac{5v}{4l_2}=212.5\text{Hz}\Rightarrow l_2=2.0\text{m}$

$\frac{7v}{4l_3}=212.5\text{Hz}\Rightarrow l_3=2.8\text{m}$

$\frac{9v}{4l_4}=212.5\text{Hz}\Rightarrow l_4=3.6\text{m}$

Alternatively, the heights of the water levels are
$(3.6-0.4)=3.2$ m, $(3.6-1.2)=2.4$ m, $(3.6-2.0)=1.6$ m, and $(3.6-2.8)=0.8$ m.
Let A represent the area of the cross-section of the pipe, and let a represent the area of the cross-section of the hole.
So, $A=\pi(2\times10^{-2})^2=1.26\times10^{-3}\text{ m}^2$
And, $a=\pi(10^{-3})^2=3.14\times10^{-6}\text{ m}^2$
Velocity of efflux, $v=\sqrt{2gH}$
Also, continuity equation is given by,

$$a\sqrt{2gH}=A\frac{-dH}{dt}$$

Hence, the rate of fall of the water level in the pipe

$$\frac{-dH}{dt}=\frac{a}{A}\sqrt{2gH}$$

Putting in the values, we get,

$$\frac{-dH}{dt}=1.11\times10^{-2}\sqrt{H}$$

During the interval between the first two resonances, the water level decreases from 3.2 meters to 2.4 meters.

Therefore, $\frac{dH}{\sqrt{H}}=-1.11\times10^{-2}dt$

Moving on, $\int_{3.2}^{2.4}\frac{dH}{\sqrt{H}}=-1.11\times10^{-2}\int_0^t dt$

Thus, $t=43$ sec

70. [27.04] Length of pipe, $L=40$ cm $=0.40$ m
Length of string, $l=25$ cm $=0.25$ m
Mass of string, $M=2.5\text{g}=0.0025$ kg

We know that, $f=\frac{n}{2L}\sqrt{\frac{T}{\mu}}$

Now, frequency of 1st overtone of string of length l is given by,

$$f_2=\frac{1}{l}\sqrt{\frac{T}{\mu}}$$

$$=\frac{1}{0.25\text{m}}\sqrt{\frac{T}{(0.0025\text{kg}/0.25\text{m})}}=40\sqrt{T}$$

Also, fundamental frequency of closed organ pipe, $f_1=\frac{v}{4L}=\frac{320\text{m/s}}{4(0.40\text{m})}=200\text{Hz}$

It is given that beat frequency
$=8=f_2-f_1=40\sqrt{T}-200$

Therefore, $T=27.04$ N

71. [336] $f=480$ Hz
$d=5$ cm $=0.05$ m

So, $r=\frac{d}{2}=0.0025m$

$l_1=16$ cm $=0.16$ m
Now,
The end correction of tube, $e=0.6r=0.6\times0.0025\text{ m}=0.0015\text{ m}$
Also,

$$e=\frac{l_2-3l_1}{2}\Rightarrow0.0015\text{m}=\frac{l_2-(3\times0.16)}{2}$$

Therefore, $l_2=0.51$ m
So, speed of the sound in the column:
$v=2f(l_2-l_1)=2\times480\times(0.51-0.16)$
$=336$ m/s

72. Fundamental frequency of open pipe

$$f=\frac{v}{2l}$$

and fundamental frequency of closed pipe,

$$f'=\frac{v}{4(l/2)}=\frac{v}{2l}\text{ or }f'=f$$

73. $m=50.7$ kg; $V=0.0075\text{ m}^3$; $f=260$ Hz
Now,
Density,

$$\rho=\frac{m}{V}=\frac{50.7\text{kg}}{0.0075\text{m}^3}=6760\text{kg/m}^3$$

Now, when submerged in water,

$$m'=m\left(1-\frac{\sigma}{\rho}\right)=m\left(1-\frac{1000\text{kg/m}^3}{6760\text{kg/m}^3}\right)$$

$=m\times0.852$

We get, $\frac{m'}{m}=0.852$

Now, $\frac{f'}{f}=\sqrt{\frac{m'}{m}}=\sqrt{0.852}=0.923$

So,
$f'=0.923\times f=0.923\times260\text{ Hz}\approx240\text{ Hz}$

74. (a) Wavelength,

$$\lambda=\frac{v}{f}=\frac{330\text{m/s}}{440\text{Hz}}=0.75\text{m}$$

For the 2nd overtone in closed pipe,

$$L=\frac{5\lambda}{4}=\frac{5(0.75\text{m})}{4}=0.94\text{m}$$

(b) Also, we know that,

$$\Delta P=-2\Delta P_m\cos(kx)\sin(\omega t)$$

Pressure amplitude,

@FAKE_CBSE_X @RAJ_EDUNET

$R = 2\Delta P_m \cos(kx) = \Delta P_0 \cos(kx)$

$= \Delta P_0 \cos\left(\frac{2\pi}{\lambda}x\right)$

At the middle of the pipe,

$x = \frac{L}{2} = \frac{15}{32}$ m

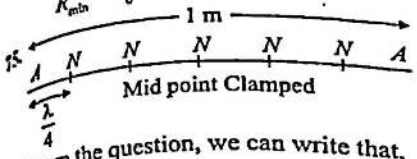
Therefore,

$R = \Delta P_0 \cos\left(\frac{2\pi}{(3/4)} \times \frac{15}{32}\right)$

$= \Delta P_0 \cos\left(\frac{5\pi}{4}\right) = \frac{\Delta P_0}{\sqrt{2}}$

(c) At the open end of the pipe, there is a pressure node, so
Pressure, $R = P_0$

(d) At the closed end of the pipe, pressure antinode is formed, so
$R_{max} = P_0 + \Delta P_0$
$R_{min} = P_0 - \Delta P_0$



From the question, we can write that,

$\frac{5\lambda}{2} = L = 1$m

Therefore, $\lambda = 0.4$ m

Now,

$v = \sqrt{\frac{Y}{\rho}} = \sqrt{\frac{2\times10^{-6}\,\text{m}}{8000\,\text{kg m}^{-3}}} = 5\times10^{3}$ m/s

So, $f = \frac{v}{\lambda} = \frac{5000\,\text{m/s}}{0.4\,\text{m}} = 12500\,\text{Hz}$

Thus, equation of standing wave:

$y = \left(A\sin\frac{2\pi}{\lambda}x + B\cos\frac{2\pi}{\lambda}x\right)\cos 2\pi\nu t$

$= (A\sin 5\pi x + B\cos 5\pi x)\cos 2\pi\nu t$

Now, at $x = \frac{1}{10}, \frac{3}{10}, \frac{5}{10}, \frac{7}{10}, \frac{9}{10}$, $y = 0$.

Thus, $A = 0$.

Standing wave equation becomes:

$y = B\cos 5\pi x \cos 25000\,\pi t$

Since, amplitude at antinode $= 2\times10^{-6}$ m,

$B = 2\times10^{-6}$ m

Hence, $y = 2\times10^{-6}\cos 5\pi x \cos 25000\pi t$

We can rewrite this as,

$y = 1\times10^{-6}(\cos 5\pi x + \cos 25000\pi t) + 1\times10^{-6}(\cos 5\pi x - \cos 25000\pi t)$

Hence, component waves are:

$y_1 = 1\times10^{-6}(\cos 5\pi x + \cos 25000\pi t)$

$y_2 = 1\times10^{-6}(\cos 5\pi x - \cos 25000\pi t)$

At a point 2 cm from the mid-point $x = (0.5 \pm 0.02)$ m, equation of motion becomes:

$y = 2\times10^{-6}\cos 5\pi(0.5 \pm 0.02)\cos 25000\pi t$

76. (a) Amplitude, $A = 4\sin\left(\frac{\pi x}{15}\right)$

At $x = 5$ cm,

$A = 4\sin\left(\frac{\pi(5\,\text{cm})}{15}\right) = 4\sin\left(\frac{\pi}{3}\right)$

$= 4\times\frac{\sqrt{3}}{2} = 2\sqrt{3}$ cm

(b) At node, $A = 4\sin\left(\frac{\pi x}{15}\right) = 0$

So, $\left(\frac{\pi x}{15}\right) = 0, \pi, 2\pi, 3\pi, \ldots$

Thus,

Nodes are at, $x = 0$ cm, 15 cm, 30 cm, ...

(c) Velocity of particle,

$v = \frac{dy}{dt} = -96\pi 4\sin\left(\frac{\pi x}{15}\right)\sin(96\pi t)$

At $x = 7.5$ cm at $t = 0.25$ s,

$v = -96\pi 4\sin\left(\frac{7.5\pi}{15}\right)\sin(96\times0.25\pi)$

$= -96\pi 4\sin\left(\frac{\pi}{2}\right)\sin(24\pi)$

(d) We can write,

$y = 4\sin\left(\frac{\pi x}{15}\right)\cos(96\pi t)$

$= 2\left(2\sin\left(\frac{\pi x}{15}\right)\cos(96\pi t)\right)$

$y = 2\left(\sin\left(96\pi t + \frac{\pi x}{15}\right) - \sin\left(96\pi t - \frac{\pi x}{15}\right)\right)$

Therefore, the two components waves are,

$y_1 = 2\sin\left(96\pi t + \frac{\pi x}{15}\right)$

$y_2 = -2\sin\left(96\pi t - \frac{\pi x}{15}\right)$

77. (a) Let v be the velocity of sound in air, v_c be the speed of the police car.
Frequency received by wall,

$f_w = \frac{v}{v - v_c} \times f$

$f = \frac{320}{320-10}\times8\times10^{3} = \frac{256000}{31}$ Hz

Now, frequency heard by the car driver,

$f' = \frac{v + v_c}{v} f_w$

$= \frac{320+10}{320}\times\frac{256000}{31}$ Hz

Therefore,

$f' = 8516.13$ Hz ≈ 8.5 kHz

78. (b) Using Doppler's equation,

$f_1 = \left(\frac{v - v_m}{v - v_s}\right)f_{car} = \left(\frac{v - v_m}{330-22}\right)176$

$= \frac{4}{7}(v - v_m)$ Hz

And,

$f_2 = \left(\frac{v + v_m}{v}\right)f_{siren} = \left(\frac{v + v_m}{330}\right)165$

$= \frac{1}{2}(v + v_m)$ Hz

Since, no beats were observed,

Hence, $f_1 - f_2 = 0 \Rightarrow f_1 = f_2$

So, $\frac{4}{7}(v - v_m) = \frac{1}{2}(v + v_m)$

Thus, $v_m = \frac{v}{15} = \frac{330\,m/s}{15} = 22$ m/s

79. (b) Using Doppler's equation,
For train A,

$f_A = \left(\frac{v + v_A}{v}\right)f_o = \left(\frac{330 + v_A}{330}\right)5$

$= 5.5$ Hz

Therefore,

$v_A = 33$ m/s

And for train B,

$f_B = \left(\frac{v + v_B}{v}\right)f_o = \left(\frac{330 + v_B}{330}\right)5 = 6$ Hz

Therefore, $v_B = 66$ m/s

Hence, $\frac{v_B}{v_A} = \frac{66\,\text{m/s}}{33\,\text{m/s}} = 2$

80. (d) Source is moving towards the observer

$f' = f\left(\frac{v}{v - v_s}\right) = 450\left(\frac{330}{330-33}\right)$

$f' = 500$ Hz

81. (b, c, d) Apparent frequency of M and N received by car at P,

$v_M = \left(\frac{v + v_0}{v}\right)v_{0M}$

$= \left(\frac{330 + \frac{50}{3}}{330}\right)118 = \frac{1040}{990}118$ Hz

$v_N = \left(\frac{v + v_0}{v}\right)v_{0N}$

$= \left(\frac{330 + \frac{50}{3}}{330}\right)121 = \frac{1040}{990}121$ Hz

Therefore, $v_P = v_N - v_M$

$= \frac{1040}{990}121 - \frac{1040}{990}118 = \frac{1040}{990}(3)$

$= \frac{1040}{330}$ Hz

Apparent frequency of M and N received by car at R,

@FAKE_CBSE_X@RAJ_EDUNET

$$v_M = \left(\frac{v - v_Q}{v}\right) v_{oM}$$

$$= \left(\frac{330 - \frac{50}{3}}{330}\right) 118 = \frac{940}{990} 118 \text{ Hz}$$

$$v_N = \left(\frac{v - v_Q}{v}\right) v_{oN}$$

$$= \left(\frac{330 - \frac{50}{3}}{330}\right) 121 = \frac{940}{990} 121 \text{ Hz}$$

Therefore, $v_R = v_N - v_M$.

$$= \frac{940}{990} 121 - \frac{940}{990} 118 = \frac{940}{990}(3) = \frac{940}{330} \text{ Hz}$$

Now, beat frequency at Q,

$v_Q = 121 - 118 = 3$ Hz

Thus, $v_P + v_R = 2v_Q$

Hence, option (*c*) is correct.

So, beat frequency,

$$n = 3\left(1 + \frac{v_o \cos\theta}{110}\right)$$

Rate of change of beat frequency,

$$\left|\frac{dn}{d\theta}\right| = 3\left(\frac{v_o \sin\theta}{110}\right)\frac{d\theta}{dt}$$

So, rate of change in beat frequency is maximum at $\theta = 90°$.

Thus, option (*b*) is also correct.

Now,

$$\tan\theta = \frac{10}{x}$$

$$\frac{d\theta}{dt} = -\frac{10v}{x^2 \sec^2\theta}$$

$$x = 10 \cot\theta$$

$$\left|\frac{dn}{dt}\right| = \frac{v_o}{110} \sin\theta \left(\frac{10v}{x^2 \sec^2\theta}\right) = k \sin^3\theta$$

Seeing the equation, we see that option (*d*) is also correct.

82. (*a, b, c*) Using Doppler's equation,

The number of waves striking the surface per second $= f'$

$$f' = \left(\frac{v - v_s}{v}\right) f = \left(\frac{c - (-v)}{c}\right) f$$

$$= \left(\frac{c + v}{c}\right) f$$

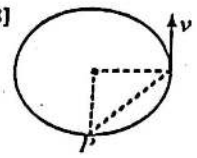
The wavelength of reflected wave is

$$\frac{c(c - v)}{f(c + v)}$$

The frequency of the reflected wave is

$$f\frac{(c + v)}{(c - v)}$$

83. [648]



$$f' = \frac{c}{c + v\cos 45°} f$$

$$f' = \frac{324}{324 + 4\sqrt{2} \times \frac{1}{\sqrt{2}}} \times 656$$

$$= \frac{324}{328} \times 656$$

$f' = 324 \times 2 = 648$ Hz

84. [8.2] $f_{(P \text{ from } S_2)} = 656$Hz

$$f_{P(\text{from } S_1)} = \frac{c}{c - v} f = \frac{656 \times 324}{324 - 4}$$

$$= \frac{656 \times 324}{320} = 664.2 \text{ Hz}$$

$\Rightarrow \Delta f = 664.2 - 656 = 8.2$Hz

85. (*a, d*) $f = f_s\left(\frac{v}{v - u}\right)$

(*a*) $f = f_0\left(\frac{v}{v - 0.8v}\right) = 5f_0$

(*b*) $f = 2f_0\left(\frac{v}{v - 0.8v}\right) = 10f_0$

(*c*) $f = 0.5f_0\left(\frac{v}{v - 0.8v}\right) = 2.5f_0$

(*d*) $f = 1.5f_0\left(\frac{v}{v - 0.5v}\right) = 3f_0$

close

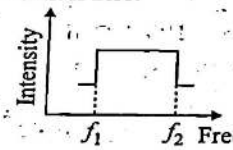
All odd harmonics are available in closed pipe therefore

86. (*b*) Now, speed of the whistle for $A = 340 + v_A$

$= 340 + 20 = 360$ m/s

And, speed of the whistle for $B = 340 - (v_B) = 340 - 30 = 310$ m/s

87. (*a*) Since the passengers in train A are moving at a uniform speed of 20m/s, the distribution of sound intensity of the whistle is uniform. There is no relative motion between the train and passenger in it, so we can say that the frequency shift is zero.



88. [8] Frequency observed by O from S_2

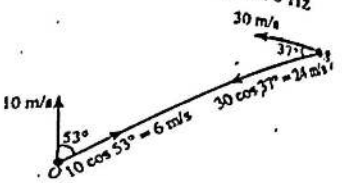
$$f_2 = \frac{330 + 10}{330} \times 120 = \frac{340}{330} \times 120$$

$= 123.63$Hz

Frequency observed by O from S_1

$$f_1 = \frac{330 + 6}{330 - 24} \times 120 = \frac{336}{306} \times 120$$

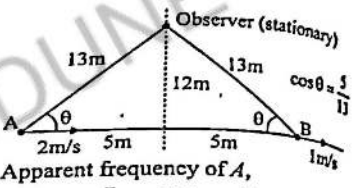
≈ 131.76 Hz



Beat frequency $= 131.76 - 123.63$

≈ 8 Hz

89. [5] We will be using Doppler's equation to solve this problem.



Apparent frequency of A,

$$f_A = 1430\left[\frac{330}{330 - 2\cos\theta}\right]$$

$$= 1430\left[1 + \frac{2\cos\theta}{330}\right]$$

Apparent frequency of B,

$$f_B = 1430\left[\frac{330}{330 + \cos\theta}\right]$$

$$= 1430\left[1 - \frac{\cos\theta}{330}\right]$$

So, $\Delta f = f_A - f_B = 1430\left[\frac{3\cos\theta}{330}\right]$

$$= 13\cos\theta = 13\left(\frac{5}{13}\right) = 5\text{Hz}$$

90. [6] Using Doppler's equation,

$$f_1 = \left(\frac{v_{sound} + v_{car}}{v_{car}}\right) f_0 = \left(\frac{330 + 2}{330}\right) 492$$

And,

$$f_2 = \left(\frac{v_{sound}}{v_{sound} - v_{car}}\right) f_1$$

$$= \left(\frac{330}{330 - 2}\right)\left(\frac{330 + 2}{330}\right) 492 = 498\text{Hz}$$

So, $\Delta f = f_2 - f_1 = 498 - 492 = 6$ Hz

91. [30] Using Doppler's equation,

When train approaches,

@EAKE_CBSE_KUNAL_RAJ_EDUNET

$$f_1 = \left(\frac{v}{v - v_s}\right) f_0 = \left(\frac{300}{300 - v_s}\right) f_0 = 2.2$$

And,

$$f_2 = \left(\frac{v}{v + v_s}\right) f_0 = \left(\frac{300}{300 + v_s}\right) f_0 = 1.8$$

On dividing the two equations,

$$\frac{2.2}{1.8} = \frac{300 + v_s}{300 - v_s}$$

Thus, $v_s = 30$ m/s

92. [403, 484]

Frequency of the whistle, $f = 440$ Hz

Length of the string, $L = 1.5$ m

Angular velocity of the string,

$\omega = 20$ rad/s

Thus, linear velocity of the whistle,

$v_s = L\omega = 1.5 \times 20 = 30$ m/s

Let the frequencies heard by the observer from source S' and S be f' and f'' respectively.

Doppler effect when source, S', approaches the stationary observer:

$$f' = f_0\left(\frac{v_{sound}}{v_{sound} - v_s}\right) = 440\left(\frac{330}{330 - 30}\right)$$

$= 484$ Hz

Doppler effect when source, S, moves away from the stationary observer:

$$f'' = f_0\left(\frac{v_{sound}}{v_{sound} + v_s}\right) = 440\left(\frac{330}{330 + 30}\right) = 403\,\text{Hz}$$

Thus, frequency range heard by the observer at large distance is 403 Hz to 484 Hz.

93. [257 Hz, 438 Hz] Amplitude, $A = 6$ m

Frequency of oscillation, $f = \frac{5}{\pi}$ Hz

Radius, $r = 3$ m

Angular velocity, $\omega = 10$ rad/s

Velocity of source, $v_s = r\omega = 30$ m/s

Velocity of detector, $v_d = 2\pi fA = 60$ m/s

Minimum frequency recorded:

$$f_{min} = f_0\left(\frac{v - v_d}{v + v_s}\right) = 340\left(\frac{340 - 60}{340 + 30}\right) = 257\,\text{Hz}$$

Maximum frequency recorded:

$$f_{max} = f_0\left(\frac{v + v_d}{v - v_s}\right) = 340\left(\frac{340 + 60}{340 - 30}\right) = 438\,\text{Hz}$$

94. [1.5] Using Doppler's equation,

$$f_1 = \left(\frac{v}{v - v_s}\right) f_0 = \left(\frac{340}{340 - v_s}\right) 340$$

And, $f_2 = \left(\frac{v}{v + v_s}\right) f_0 = \left(\frac{340}{340 + v_s}\right) 340$

So, $\Delta f = f_1 - f_2 = 3$ Hz

$$= \left(\frac{340}{340 - v_s}\right) 340 - \left(\frac{340}{340 + v_s}\right) 340$$

On solving, we get $v_s = 1.5$ m/s

95. [0.75] We know that,

$$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

$$= \frac{1}{2(0.10\,\text{m})}\sqrt{\frac{64\,\text{N}}{(0.001\,\text{kg}/0.10\,\text{m})}}$$

$= 400$ Hz

Since, it produces 1 beat per second, therefore, $f' = 400 - 1 = 399$ Hz

Using Doppler's equation,

$$f' = \left(\frac{v}{v + v_s}\right) f \Rightarrow 399 = \left(\frac{300}{300 + v_s}\right) 400$$

Thus, $v_s = 0.75$ m/s

96. [7.88] Using Doppler's equation,

$$f' = \left(\frac{v + v_0}{v - v_s}\right) f_0$$

$$= \left(\frac{300 + 5}{300 - 5}\right) 256 = 263.88\,Hz$$

Therefore,

Beat frequency, $\Delta f = 263.88 - 256 = 7.88$ Hz

97. Using Doppler's equation,

$$f' = \left(\frac{v - v_o}{v - v_s}\right) f_0 = \left(\frac{342 - (-5)}{342 - 5}\right) 200$$

$= 205.93$

Frequency of beats $= 206 - 200 = 6$ Hz

98. [True] Using Doppler's equation,

When source is directly approaching observer

Let frequency observed

$$n' = \left(\frac{v_{sound}}{v_{sound} - v}\right) n$$

When source is reflected from wall

Let frequency observed

$$n'' = \left(\frac{v_{sound}}{v_{sound} + v}\right) n$$

$\therefore$ beat frequency $= n' - n''$

Beat frequency, $\Delta f = (260 - 252) = 8$Hz

So, the observer will hear the beats.

99. (*a*) For the 1st part,

The frequency of 2nd harmonic of pipe A, $f_A = \frac{2v_A}{2L}$

The frequency of 3rd harmonic of pipe B, $f_B = \frac{3v_B}{4L}$

According to the question,

$f_A = f_B$

$$\frac{2v_A}{2L} = \frac{3v_B}{4L}, \frac{v_A}{v_B} = \frac{3}{4}$$

Therefore, $\frac{\sqrt{\frac{\gamma_A RT}{M_A}}}{\sqrt{\frac{\gamma_B RT}{M_B}}} = \frac{3}{4}$

Putting in the values, $\frac{\sqrt{\frac{(5/3)RT}{M_A}}}{\sqrt{\frac{(7/5)RT}{M_B}}} = \frac{3}{4}$

On solving, we get, $\frac{M_A}{M_B} = \frac{400}{189}$

(*b*) For the 2nd part,

When pipe B is closed at both ends, its frequency, $f_B = \frac{v_B}{2L}$

Thus, $\frac{f_A}{f_B} = \frac{v_A}{v_B} = \frac{3}{4}$

100. (*a*) Speed of boat, $u = 10$ m/s

Speed of river stream, $w = 2$ m/s

Speed of sound inside water,

$$v = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{2.088 \times 10^9\,Pa}{10^3\,kg/m^3}} = 1445\,\text{m/s}$$

Frequency of wave inside water,

$$f = \frac{v}{\lambda} = \frac{1445\,\text{m/s}}{0.01445\,\text{m}} = 10^5\,\text{Hz}$$

Apparent frequency is given by Doppler's equation,

$$f' = \frac{v + w}{v + w - u} f = \frac{1445 + 2}{1445 + 2 - 10} 10^5\,\text{Hz}$$

$= 100.7$ kHz

(*b*) Speed of sound in air,

$$v = \sqrt{\frac{\gamma RT}{M}} = \sqrt{\frac{1.4 \times 8.31 \times 293}{28.8 \times 10^{-3}}}$$

$= 344$ m/s

Speed of wind, $w = 5$ m/s

Therefore,

Apparent frequency is given by Doppler's equation,

$$f' = \frac{v - w}{v - w - u} f = \frac{344 - 5}{344 - 5 - 10} 10^5\,\text{Hz}$$

$= 103.04$ kHz

101. Using Doppler's equation,

Frequency directly heard by the motorist,

$$f_1 = \left(\frac{v + v_m}{v + v_b}\right) f$$

@NKE_CBSE_X@RAJ_SIR_NET

And frequency after reflection,

$$f_2 = \left(\frac{v + v_m}{v - v_b}\right) f$$

So,

Beat frequency $= \Delta f = f_2 - f_1$

$$= \left(\frac{v + v_m}{v - v_b}\right) f - \left(\frac{v + v_m}{v + v_b}\right) f$$

Thus, $\Delta f = \frac{2v_b(v + v_m)}{v^2 - v_b^2} f$

102. (*a*) Apparent frequency using Doppler's equation,

$$f' = f \frac{(v + v_w)}{(v + v_w) - v_s}$$

$$= 580 \frac{(1200 + 40)}{(1200 + 40) - 40} = 599.33 \text{ Hz}$$

(*b*) Now,

Time taken by the train to reach from one point to another, $t = \frac{1 - x}{40}$ hr

Time taken by the sound to reach after reflection,

$$t = \left(\frac{1}{v + v_w} + \frac{x}{v - v_w}\right) \text{hr}$$

$$= \frac{1}{1200 + 40} + \frac{x}{1200 - 40}$$

$$= \frac{1}{1240} + \frac{x}{1160}$$

Thus, $\frac{1 - x}{40} = \frac{1}{1240} + \frac{x}{1160}$

Now, frequency received by the driver,

$$f'' = f' \frac{(v - v_w) + v_o}{(v - v_w)} = 620 \text{ Hz}$$

Also, $x = \frac{(v - v_w) \times (v + v_w - v_s)}{(v + v_w) \times (v - v_w + v_s)}$

$$= \frac{(1200 - 40) \times (1200 + 40 - 40)}{(1200 + 40) \times (1200 - 40 + 40)}$$

$= 0.935$ km

Thus, the echo is heard when the train is 935 m from the hill.

@FAKE_CBSE X @RAJ_EDUNET

1 Electric Charges and Fields

Scan for Sol.

JEE-Main

Coulomb's Law

1. Force between two point charges q_1 and q_2 placed in vacuum at 'r' cm apart is F. Force between them when placed in a medium having dielectric K = 5 at 'r/5' cm apart will be: **[31 Jan, 2024 (Shift-II)]**
   (a) F/25 (b) 5F (c) F/5 (d) 25F

2. Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle θ with each other. When suspended in water the angle remains the same. If density of the material of the sphere is 1.5 g/cc, the dielectric constant of water will be _____

3. Two identical charged spheres are suspended by string of equal lengths. The string make an angle of 37° with each other. When suspended in a liquid of density 0.7 g/cm³, the angle remains same. If density of material of the sphere is 1.4 g/cm³, the dielectric constant of the liquid is _____. $\left(\tan 37° = \frac{3}{4}\right)$ **[30 Jan, 2024 (Shift-II)]**

4. A thin metallic wire having cross sectional area of 10^{-4} m² is used to make a ring of radius 30 cm. A positive charge of 2π C is uniformly distributed over the ring, while another positive charge of 30 pC is kept at the centre of the ring. The tension in the ring is _____ N; provided that the ring does not get deformed (neglect the influence of gravity). **[27 Jan, 2024 (Shift-I)]**
   (given $\frac{1}{4\pi\epsilon_0} = 9\times10^9$ SI units)

5. Suppose a uniformly charged wall provides a uniform electric field of 2×10^4 N/C normally. A charged particle of mass 2 g being suspended through a silk thread of length 20 cm and remain stayed at a distance of 10 cm from the wall. Then the charge on the particle will be $\frac{1}{\sqrt{x}}\mu C$ where $x =$ _____. [use g = 10 m/s²] **[1 Feb, 2024 (Shift-II)]**

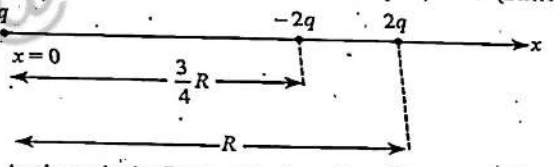
6. In hydrogen like system the ratio of coulombian force and gravitational force between an electron and a proton is in the order of: **[05 April, 2024 (Shift-I)]**
   (a) 10^{39} (b) 10^{19} (c) 10^{29} (d) 10^{36}

7. Two identical conducting spheres P and S with charge Q on each, repel each other with a force 16N. A third identical uncharged conducting sphere R is successively brought in contact with the two spheres. The new force of repulsion between P and S is: **[06 April, 2024 (Shift-II)]**
   (a) 4 N (b) 6 N (c) 1 N (d) 12 N

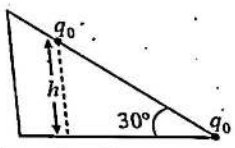
8. If two charges q_1 and q_2 are separated with distance 'd' and placed in a medium of dielectric constant K. What will be the equivalent distance between charges in air for the same electrostatic force? **[24 Jan, 2023 (Shift-I)]**
   (a) $d\sqrt{k}$ (b) $k\sqrt{d}$ (c) $1.5d\sqrt{k}$ (d) $2d\sqrt{k}$

9. A 10 μC charge is divided into two parts and placed at 1 cm distance so that the repulsive force between them is maximum. The charges of the two parts are: **[13 April, 2023 (Shift-II)]**
   (a) 9 μC, 1 μC (b) 5 μC, 5 μC
   (c) 7 μC, 3 μC (d) 8 μC, 2 μC

10. Three point charges $q, -2q$ and $2q$ are placed on x-axis at a distance $x = 0, x = \frac{3}{4}R$ and $x = R$ respectively from origin as shown. If $q = 2\times10^{-6}$ C and $R = 2$ cm, the magnitude of net force experienced by the charge $-2q$ is _____ N. **[13 April, 2023 (Shift-II)]**



11. As shown in the figure. a configuration of two equal point charges ($q_0 = +2\mu$ C), is placed on an inclined plane. Mass of each point charge is 20 g. Assume that there is no friction between charge and plane. For the system of two point charges to be in equilibrium (at rest) the height $h = x \times 10^{-3}$ m The value of x is _____ mm.
    (Take $\frac{1}{4\pi\varepsilon_0} = 9\times10^9\ N\,m^2C^{-2}$, $g = 10\,ms^{-1}$)
    [11 April, 2023 (Shift-I)]



12. Two equal positive point charges are separated by a distance 2a. The distance of a point from the centre of the line joining two charges on the equatorial line (perpendicular bisector) at which force experienced by a test charge q_0 becomes maximum is $\frac{a}{\sqrt{x}}$. The value of x is **[1 Feb, 2023 (Shift-I)]**

@KT_CLICK@AJ_BOOKS

13. A point charge $q_1 = 4q_0$ is placed at origin. Another point charge $q_2 = -q_0$ is placed at $x = 12$ cm. Charge of proton is q_0. The proton is placed on x-axis so that the electrostatic force on the proton is zero. In this situation, the position of the proton from the origin is _____ cm. [29 Jan, 2023 (Shift-I)]

14. Two identical positive charges Q each are fixed at a distance of '$2a$' apart from each other. Another point charge q_0 with mass 'm' is placed at midpoint between two fixed charges. For a small displacement along the line joining the fixed charges, the charge q_0 executes SHM. The time period of oscillation of charge q_0 will be:
[27 July, 2022 (Shift-I)]

(a) $\sqrt{\frac{4\pi^3\varepsilon_0 ma^3}{q_0 Q}}$ (b) $\sqrt{\frac{q_0 Q}{4\pi^3\varepsilon_0 ma^3}}$

(c) $\sqrt{\frac{2\pi^2\varepsilon_0 ma^3}{q_0 Q}}$ (d) $\sqrt{\frac{8\pi^3\varepsilon_0 ma^3}{q_0 Q}}$

15. Two identical metallic spheres A and B when placed at certain distance in air repel each other with force of F. Another identical uncharged sphere C is first placed in contact with A and then in contact with B and finally placed at midpoint between sphere A and B. The force experienced by sphere C will be:
[29 July, 2022 (Shift-II)]

(a) $3F/2$ (b) $3F/4$ (c) F (d) $2F$

16. Two point charges Q each are placed at a distance d apart. A third point charge q is placed at a distance x from mid-point on the perpendicular bisector. The value of x at which charge q will experience the maximum Coulomb's force is:
[29 June, 2022 (Shift-II)]

(a) $x = d$ (b) $x = \frac{d}{2}$ (c) $x = \frac{d}{\sqrt{2}}$ (d) $x = \frac{d}{2\sqrt{2}}$

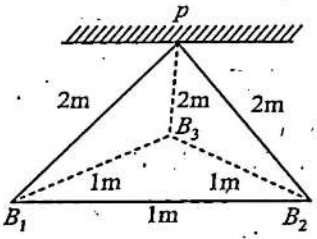
17. Two identical charged particles each having a mass 10 g and charge 2.0×10^{-7}C are placed on a horizontal table with a separation of L between them such that they stay in limited equilibrium. If the coefficient of friction between each particle and the table is 0.25, find the value of L.
[Use $g = 10 ms^{-2}$] [24 June, 2022 (Shift-II)]

(a) 12 cm (b) 10 cm (c) 8 cm (d) 5 cm

18. A charge of 4μC is to be divided into two. The distance between the two divided charges is constant. The magnitude of the divided charges so that the force between them is maximum, will be:
[27 July, 2022 (Shift-II)]

(a) 1μC and 3μC (b) 2μC and 2μC
(c) 0 and 4μC (d) 1.5μC and 2.5μC

19. Three identical charged balls each of charge 2C are suspended from a common point P by silk threads of 2 m each (as shown in figure). They form an equilateral triangle of side 1 m.
The ratio of net force on a charged ball to the force between any two charged balls will be [27 June, 2022 (Shift-II)]



(a) 1 : 1 (b) 1 : 4 (c) $\sqrt{3}$: 2 (d) $\sqrt{3}$: 1

20. Three point charges of magnitude 5μC, 0.16μC, and 0.3μC are located at the vertices A, B, C of a right angled triangle whose sides are $AB = 3$cm, $BC = 3\sqrt{2}$ cm and $CA = 3$cm and point A is the right angle corner. Charge at point A experiences _____ N of electrostatic force due to the other two charges. [26 July, 2022 (Shift-II)]

21. A disk of radius R with uniform positive charge density σ is placed on the xy plane with its center at the origin. The Coulomb potential along the z-axis is

$$V(z) = \frac{\sigma}{2\varepsilon_0}\left(\sqrt{R^2 + z^2} - z\right)$$

A particle of positive charge q is placed initially at rest at a point on the z axis with $z = z_0$ and $z_0 > 0$. In addition to the Coulomb force, the particle experiences a vertical force $\vec{F} = -c\hat{k}$ with $c > 0$. Let $\beta = \frac{2c\varepsilon_0}{q\sigma}$. Which of the following statements is (are) correct?
[JEE Adv, 2022]

(a) For $\beta = \frac{1}{4}$ and $z_0 = \frac{25}{7}R$, the particle reaches the origin

(b) For $\beta = \frac{1}{4}$ and $z_0 = \frac{3}{7}R$, the particle reaches the origin

(c) For $\beta = \frac{1}{4}$ and $z_0 = \frac{R}{\sqrt{3}}$, the particle returns back to $z = z_0$

(d) For $\beta > 1$ and $z_0 > 0$, the particle always reaches the origin

22. Two identical tennis balls each having mass 'm' and charge 'q' are suspended from a fixed point by threads of length 'l'. What is the equilibrium separation when each thread makes a small angle 'θ' with the vertical? [27 July, 2021 (Shift-I)]

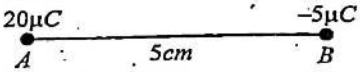
(a) $x = \left(\frac{q^2\ell}{2\pi\varepsilon_0 mg}\right)^{1/2}$ (b) $x = \left(\frac{q^2\ell}{2\pi\varepsilon_0 mg}\right)^{1/3}$

(c) $x = \left(\frac{q^2\ell^2}{2\pi\varepsilon_0 m^2 g^2}\right)^{1/3}$ (d) $x = \left(\frac{q^2\ell^2}{2\pi\varepsilon_0 m^2 g}\right)^{1/3}$

23. A certain charge Q is divided into parts q and $(Q - q)$. How should the charges Q and q be divided so that q and $(Q - q)$ placed at a certain distance apart experience maximum electrostatic repulsion?
[20 July, 2021 (Shift-I)]

(a) $Q = \frac{q}{2}$ (b) $Q = 4q$ (c) $Q = 2q$ (d) $Q = 3q$

24. Two particles A and B having charges 20 μC and –5 μC respectively are held fixed with a separation of 5 cm. At what position a third charged particle should be placed so that it does not experience a net electric force? [31 Aug, 2021 (Shift-I)]



(a) At 5 cm from 20 μC on the left side of system.
(b) At 1.25 cm from –5 μC between two charges.
(c) At midpoint between two charges.
(d) At 5 cm from –5 μC on the right side.

25. Two electrons each are fixed at a distance '$2d$'. A third charge proton placed at the midpoint is displaced slightly by a distance x ($x << d$) perpendicular to the line joining the two fixed charges. Proton will execute simple harmonic motion having angular frequency:
(m = mass of charged particle) [24 Feb, 2021 (Shift-II)]

(a) $\left(\frac{2q^2}{\pi\varepsilon_0 md^3}\right)^{\frac{1}{2}}$ (b) $\left(\frac{2\pi\varepsilon_0 md^3}{q^2}\right)^{\frac{1}{2}}$

(c) $\left(\frac{q^2}{2\pi\varepsilon_0 md^3}\right)^{\frac{1}{2}}$ (d) $\left(\frac{2\pi\varepsilon_0 md^3}{2q^2}\right)^{\frac{1}{2}}$

@TAKE_CBSE_@RAJEDUCET

26. Two small spheres each of mass 10 mg are suspended from a point by threads 0.5 m long. They are equally charged and repel each other to a distance of 0.20 m. Then charge on each of the sphere is $\frac{a}{21}\times10^{-8}C$. The value of '$a$' will be_____ **[25 Feb, 2021 (Shift-II)]**

27. A particle of mass 1 mg and charge q is lying at the mid-point of two stationary particles kept at a distance '2 m' when each is carrying same charge 'q'. If the free charged particle is displaced from its equilibrium position through distance 'x' ($x << 1$m). The particle executes SHM. Its angular frequency of oscillation will be _____ $\times10^4$ rad/s if $q^2 = 10C^2$. **[25 July, 2021 (Shift-I)]**

28. Two identical conducting spheres with negligible volume have 2.1nC and −0.1 nC charges, respectively. They are brought into contact and then separated by a distance of 0.5 m. The electrostatic force acting between the spheres is _____ $\times10^{-9}$ N $\left[\text{Given}: 4\pi\epsilon_0=\frac{1}{9\times10^9}\text{SI Unit}\right]$ **[25 Feb, 2021 (Shift-II)]**

29. An oil drop of radius 2 mm with a density 3 gcm^{-3} is held stationary under a constant electric field 3.55×10^5Vm^{-1} in the Millikan's oil drop experiment. What is the number of excess electrons that the oil drop will possess? (Consider g = 9.81 m/s^2.) **[18 March, 2021 (Shift-I)]**

(a) 1.73×10^{10} (b) 48.8×10^{11}
(c) 1.73×10^{12} (d) 17.3×10^{10}

30. An infinite number of point charges, each carrying 1 μC charge, are placed along the y-axis at, y = 1m, 2m, 4m, 8m. The total force on a 1 C point charge, placed at the origin, is $x\times10^3$ N. The value of x to the nearest integer, is_____ [Take $\frac{1}{4\pi\varepsilon_0}=9\times10^9\text{Nm}^2/\text{C}^2$] **[18 March, 2021 (Shift-II)]**

31. Consider the force F on a charge 'q' due to a uniformly charged spherical shell of radius R carrying charge Q distributed uniformly over it. Which one of the following statements is true for F, if 'q' is placed at distance r from the center of the shell? **[6 Sep, 2020 (Shift-II)]**

(a) $F=\frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ for all r (b) $\frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}>F>0$ For $r<R$
(c) $F=\frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ for $r>R$ (d) $F=\frac{1}{4\pi\varepsilon_0}\frac{Qq}{R^2}$ for $r<R$

32. Two identical non-conducting solid spheres of same mass and charge are suspended in air from a common point by two non-conducting, massless strings of same length. At equilibrium, the angle between the strings is α. The spheres are now immersed in a dielectric liquid of density 800 kg/m^3 and dielectric constant 21. If the angle between the strings remains the same after the immersion, then **[JEE Adv, 2020]**
(a) electric force between the spheres remains unchanged
(b) electric force between the spheres reduces
(c) mass density of the spheres is 840 kg m^{-3}
(d) the tension in the strings holding the spheres remains unchanged

33. Let a total charge $2Q$ be distributed in a sphere of radius R, with the charge density given by $\rho(r) = kr$, where r is the distance from the centre. Two charges A and B, of $-Q$ each, are placed on diametrically opposite points, at equal distance, a, from the centre. If A and B do not experience any force, then **[12 April, 2019 (Shift-II)]**

(a) $a=\frac{3R}{2^{1/4}}$ (b) $a=R/\sqrt{3}$
(c) $a=8^{-1/4}R$ (d) $a=2^{-1/4}R$

34. Three charges $+Q$, q, $+Q$ are placed respectively, at distance, 0, $d/2$ and d from the origin, on the x-axis. If the net force experienced by $+Q$, placed at $x = 0$, is zero, then value of q is **[9 Jan, 2019 (Shift-I)]**
(a) $-Q/4$ (b) $+Q/2$ (c) $+Q/4$ (d) $-Q/2$

35. Charge is distributed within a sphere of radius R with a volume charge density $\rho(r)=\frac{A}{r^2}e^{-2r/a}$, where A and a are constants. If Q is the total charge of this charge distribution the radius R is **[9 Jan, 2019 (Shift-II)]**

(a) $a\log\left(1-\frac{Q}{2\pi aA}\right)$ (b) $\frac{a}{2}\log\left(\frac{1}{1-\frac{Q}{2\pi aA}}\right)$
(c) $a\log\left(\frac{1}{1-\frac{Q}{2\pi aA}}\right)$ (d) $\frac{a}{2}\log\left(1-\frac{1}{2\pi aA}\right)$

36. The bob of a simple pendulum has mass 2g and a charge of 5.0 μC. It is at rest in a uniform horizontal electric field of intensity 2000 V/m. At equilibrium, the angle that the pendulum makes with the vertical is (Take g = 10 m/s^2) **[8 April, 2019 (Shift-I)]**
(a) $\tan^{-1}(5.0)$ (b) $\tan^{-1}(2.0)$ (c) $\tan^{-1}(0.5)$ (d) $\tan^{-1}(0.2)$

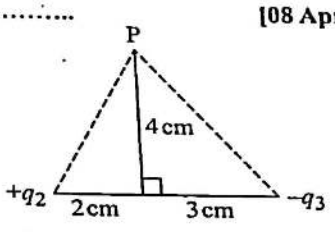
37. The function of time representing a simple harmonic motion with a period of $\frac{\pi}{\omega}$ is: **[18 Mar (Shift-II)]**
(a) $\cos(\omega t)+\cos(2\omega t)+\cos(3\omega t)$
(b) $\sin^2(\omega t)$
(c) $\sin(\omega t)+\cos(\omega t)$
(d) $3\cos\left(\frac{\pi}{4}-2\omega t\right)$

Electric Field and Field Lines

38. Two charges q and $3q$ are separated by a distance 'r' in air. At a distance x from charge q, the resultant electric field is zero. The value of x is: **[31 Jan, 2024 (Shift-I)]**

(a) $\frac{\left(1+\sqrt{3}\right)}{r}$ (b) $\frac{r}{3\left(1+\sqrt{3}\right)}$
(c) $\frac{r}{\left(1+\sqrt{3}\right)}$ (d) $r\left(1+\sqrt{3}\right)$

39. If the net electric field at point P along Y axis is zero, then the ratio of $\left|\frac{q_2}{q_3}\right|$ is $\frac{8}{5\sqrt{x}}$, where x = ... **[08 April, 2024 (Shift-II)]**

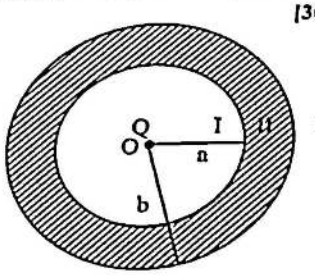


40. A point charge of 10μC is placed at the origin. At what location on the X-axis should a point charge of 40μC be placed so that the net electric field is zero at x = 2cm on the X-axis? **[25 Jan, 2023 (Shift-II)]**
(a) x = 6 cm (b) x = 4 cm (c) x = 8 cm (d) x = −4 cm

© JEE CBSE @RAJ EDUPOINT

41. As shown in the figure, a point charge Q is placed at the centre of conducting spherical shell of inner radius a and outer radius b. The electric field due to charge Q in three different regions I, II and III is given by: ($I : r < a$, $II : a < r < b$, $III : r > b$)

[30 Jan, 2023 (Shift-II)]



(a) $E_I = 0, E_{II} = 0, E_{III} \neq 0$ (b) $E_I \neq 0, E_{II} = 0, E_{III} \neq 0$
(c) $E_I \neq 0, E_{II} = 0, E_{III} = 0$ (d) $E_I = 0, E_{II} = 0, E_{III} = 0$

42. A thin infinite sheet charge and an infinite line charge of respective charge densities $+\sigma$ and $+\lambda$ are placed parallel at 5 m distance from each other. Points 'P' and 'Q' are at $\frac{3}{\pi}$m and $\frac{4}{\pi}$m perpendicular distance from line charge towards sheet charge, respectively. 'E_P' and 'E_Q' are the magnitudes of resultant electric field intensities at point 'P' and 'Q', respectively. If $\frac{E_P}{E_Q} = \frac{4}{a}$ for $2|\sigma| = |\lambda|$. Then the value of a is_____.

[13 April, 2023 (Shift-I)]

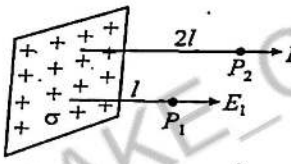
43. Two point charges A and B of magnitude $+8\times10^{-6}$ C and -8×10^{-6} C respectively are placed at a distance d apart. The electric field at the middle point O between the charges is 6.4×10^{4} NC^{-1}. The distance 'd' between the point charges A and B is:

[28 June, 2022 (Shift-II)]

(a) 2.0 m (b) 3.0 m (c) 1.0 m (d) 4.0 m

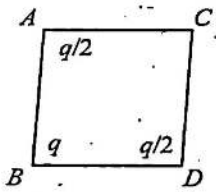
44. In the figure, a very large plane sheet of positive charge is shown. P_1 and P_2 are two points at distance l and 2 l from the charge distribution. If σ is the surface charge density, then the magnitude of electric fields E_1 and E_2 at P_1 and P_2 respectively are

[25 June, 2022 (Shift-I)]



(a) $E_1 = \sigma/\epsilon_0, E_2 = \sigma/2\epsilon_0$ (b) $E_1 = 2\sigma/\epsilon_0, E_2 = \sigma/\epsilon_0$
(c) $E_1 = E_2 = \sigma/2\epsilon_0$ (d) $E_1 = E_2 = \sigma/\epsilon_0$

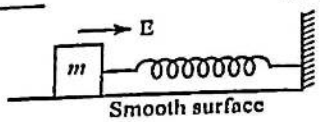
45. The three charges $q/2$, q and $q/2$ are placed at the corners A, B and C of a square of side 'a' as shown in figure. The magnitude of electric field (E) at the corner D of the square, is [28 June, 2022 (Shift-I)]



(a) $\frac{q}{4\pi\epsilon_0 a^2}\left(\frac{1}{\sqrt{2}}+\frac{1}{2}\right)$ (b) $\frac{q}{4\pi\epsilon_0 a^2}\left(1+\frac{1}{\sqrt{2}}\right)$
(c) $\frac{q}{4\pi\epsilon_0 a^2}\left(1-\frac{1}{\sqrt{2}}\right)$ (d) $\frac{q}{4\pi\epsilon_0 a^2}\left(\frac{1}{\sqrt{2}}-\frac{1}{2}\right)$

46. A block of mass 'm' (as shown in figure) moving with kinetic energy E compresses a spring through a distance 25 cm when, its speed is halved. The value of spring constant of used spring will be n[] Nm^{-1} for n = _____

[28 July, 2022 (Shift-I)]



47. An oil drop of radius 2 mm with a density 3 gcm^{-3} is held stationary under a constant electric field 3.55×10^{5}Vm^{-1} in the Millikan's oil drop experiment. What is the number of excess electrons that the oil drop will possess? (Consider g = 9.81 m/s^2.)

[18 March, 2021 (Shift-I)]

(a) 1.73×10^{10} (b) 48.8×10^{11}
(c) 1.73×10^{12} (d) 17.3×10^{10}

48. A uniformly charged disc of radius R having surface charge density σ is placed in the xy plane with its center at the origin. Find the electric field intensity along the z-axis at a distance Z from origin:

[27 Aug, 2021 (Shift-I)]

(a) $E = \frac{\sigma}{2\epsilon_0}\left(1+\frac{Z}{\left(Z^2+R^2\right)^{1/2}}\right)$

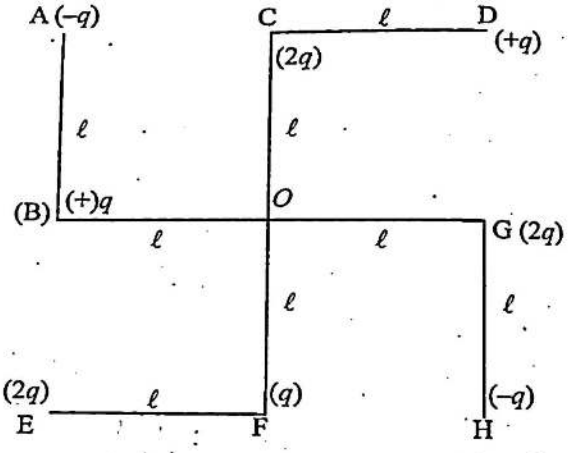
(b) $E = \frac{\sigma}{2\epsilon_0}\left(1-\frac{Z}{\left(Z^2+R^2\right)^{1/2}}\right)$

(c) $E = \frac{2\epsilon_0}{\sigma}\left(\frac{1}{\left(Z^2+R^2\right)^{1/2}}+Z\right)$

(d) $E = \frac{\sigma}{2\epsilon_0}\left(\frac{1}{\left(Z^2+R^2\right)}+\frac{1}{Z^2}\right)$

49. What will be the magnitude of electric field at point O as shown in figure? Each side of the figure is ℓ and perpendicular to each other?

[27 July, 2021 (Shift-II)]



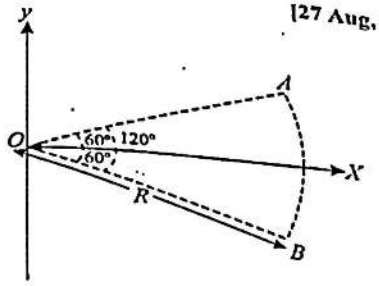
(a) $\frac{1}{4\pi\epsilon_0}\frac{q}{\left(2\ell^2\right)}\left(2\sqrt{2}-1\right)$ (b) $\frac{q}{4\pi\epsilon_0(2\ell)^2}$

(c) $\frac{1}{4\pi\epsilon_0}\frac{q}{\ell^2}$ (d) $\frac{1}{4\pi\epsilon_0}\frac{2q}{2\ell^2}\left(\sqrt{2}\right)$

@TAKE_CBSE_X @RALEDUNET

50. Figure shows a rod AB, which is bent in a 120° circular arc of radius R. A charge $(-Q)$ is uniformly distributed over rod AB. What is the electric field $\vec{E}$ at the centre of curvature O?

[27 Aug, 2021 (Shift-II)]

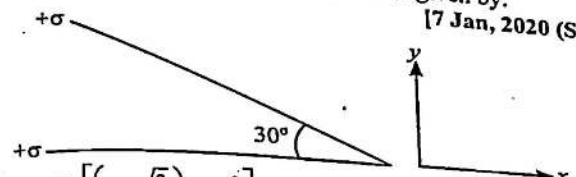


(a) $\frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}(-\hat{i})$ (b) $\frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}(\hat{i})$

(c) $\frac{3\sqrt{3}Q}{8\pi\varepsilon_0 R^2}(\hat{i})$ (d) $\frac{3\sqrt{3}Q}{16\pi^2\varepsilon_0 R^2}(\hat{i})$

51. Two infinite planes each with uniform surface charge density $+\sigma$ are kept in such a way that the angle between them is 30°. The electric field in the region shown between them is given by:

[7 Jan, 2020 (Shift-I)]

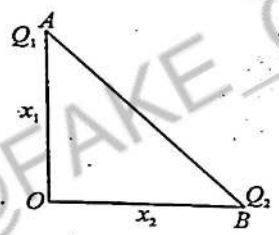


(a) $\frac{\sigma}{2\varepsilon_0}\left[\left(1-\frac{\sqrt{3}}{2}\right)\hat{y}-\frac{\hat{x}}{2}\right]$ (b) $\frac{\sigma}{2\varepsilon_0}\left[\left(1+\sqrt{3}\right)\hat{y}-\frac{\hat{x}}{2}\right]$

(c) $\frac{\sigma}{2\varepsilon_0}\left[\left(1+\sqrt{3}\right)\hat{y}+\frac{\hat{x}}{2}\right]$ (d) $\frac{\sigma}{\varepsilon_0}\left[\left(1+\frac{\sqrt{3}}{2}\right)\hat{y}+\frac{\hat{x}}{2}\right]$

52. Charges Q_1 and Q_2 are at points A and B of a right angle triangle OAB (see figure). The resultant electric field at point O is perpendicular to the hypotenuse, then Q_1/Q_2 is proportional to

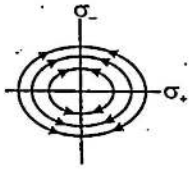
[6 Sep, 2020 (Shift-I)]

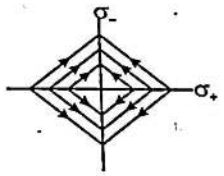


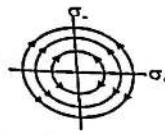
(a) $\frac{x_1^3}{x_2^3}$ (b) $\frac{x_2^2}{x_1^2}$ (c) $\frac{x_1}{x_2}$ (d) $\frac{x_2}{x_1}$

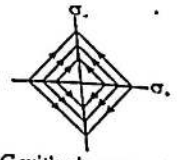
53. Two charged thin infinite plane sheets of uniform surface charge density σ_+ and σ_-, where $|\sigma_+| > |\sigma_-|$, intersect at right angle. Which of the following best represents the electric field lines for this system?

[4 Sep, 2020 (Shift-I)]

(a) 

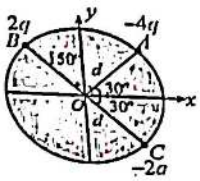
(b) 

(c) 

(d) 

54. Three charged particles A, B and C with charges $-4q$, $2q$ and $-2q$ are present on the circumference of a circle of radius d. The charged particles A, C and center O of the circle formed an equilateral triangle as shown in figure. Electric field at O along x-direction is

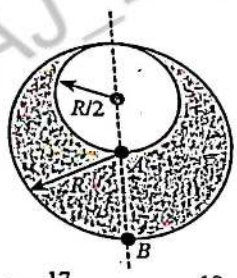
[8 Jan, 2020 (Shift-I)]



(a) $\frac{\sqrt{3}q}{\pi\varepsilon_0 d^2}$ (b) $\frac{\sqrt{3}q}{4\pi\varepsilon_0 d^2}$ (c) $\frac{3\sqrt{3}q}{4\pi\varepsilon_0 d^2}$ (d) $\frac{2\sqrt{3}q}{\pi\varepsilon_0 d^2}$

55. Consider a sphere of radius R which carries a uniform charge density ρ. If a sphere of radius $R/2$ is carved out of it, as shown the ratio $\frac{|\vec{E}_A|}{|\vec{E}_B|}$ of magnitude of electric field $\vec{E}_A$ and $\vec{E}_B$, respectively, at point A and B due to the remaining portion is:

[9 Jan, 2020 (Shift-I)]



(a) $\frac{18}{34}$ (b) $\frac{17}{54}$ (c) $\frac{18}{54}$ (d) $\frac{21}{34}$

56. Two point charges $q_1\left(\sqrt{10}\mu C\right)$ and $q_2(-25\ \mu C)$ are placed on the x-axis at $x = 1$ m and $x = 4$ m respectively. The electric field (in V/m) at a point $y = 3$ m on y-axis is,

$\left[\text{take}\frac{1}{4\pi\varepsilon_0} = 9\times10^9\ Nm^2C^{-2}\right]$ [9 Jan, 2019 (Shift-II)]

(a) $\left(63\hat{i}-27\hat{i}\right)\times10^2$ (b) $\left(-63\hat{i}-27\hat{i}\right)\times10^2$

(c) $\left(81\hat{i}-81\hat{i}\right)\times10^2$ (d) $\left(-81\hat{i}-81\hat{i}\right)\times10^2$

57. For a uniformly charged ring of radius R, the electric field on its axis has the largest magnitude at a distance h from its centre. Then value of h is

[9 Jan, 2019 (Shift-I)]

(a) $\frac{R}{\sqrt{5}}$ (b) $\frac{R}{\sqrt{2}}$ (c) R (d) $R\sqrt{2}$

58. Four point charges $-q$, $+q$, $+q$ and $-q$ are placed on y-axis at $y = -2d$, $y = -d$, $y = +d$ and $y = +2d$, respectively. The magnitude of the electric field E at a point on the x-axis at $x = D$, with $D >> d$, will vary as

[9 April, 2019 (Shift-II)]

(a) $E \propto \frac{1}{D}$ (b) $E \propto \frac{1}{D^3}$ (c) $E \propto \frac{1}{D^2}$ (d) $E \propto \frac{1}{D^4}$

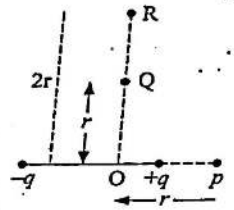
@FAKE_OREX @RAJ_EDUCET

Electric Dipole, Force & Torque on Dipole

59. Two charges of $-4\mu C$ and $+4\mu C$ are placed at the points $A(1, 0, 4)$ m and $B(2, -1, 5)$ located in an electric field $\vec{E} = 0.20\hat{i}$ V / cm. The magnitude of the torque acting on the dipole is $8\sqrt{\alpha} \times 10^{-5}$ Nm, where $\alpha =$ _____. **[27 Jan, 2024 (Shift-II)]**

60. The electric field at point p due to an electric dipole is E. The electric field at point R on equitorial line will be E/x. The value of x :

[05 April, 2024 (Shift-II)]



61. The electric field due to a short electric dipole at a large distance (r) from center of dipole on the equatorial plane varies with distance as: **[15 April, 2023 (Shift-I)]**

(a) r (b) $\frac{1}{r}$ (c) $\frac{1}{r^3}$ (d) $\frac{1}{r^2}$

62. Two charges each of magnitude 0.01 C and separated by a distance of 0.4 mm constitute an electric dipole. If the dipole is placed in an uniform electric field '$\vec{E}$' of 10 dyne/C making 30° angle with $\vec{E}$, the magnitude of torque acting on dipole is **[13 April, 2023 (Shift-I)]**

(a) 4.0×10^{-10} Nm (b) 2.0×10^{-10} Nm
(c) 1.0×10^{-8} Nm (d) 1.5×10^{-9} Nm

63. A dipole comprises of two charged particles of identical magnitude q and opposite in nature. The mass m of the positive charged particle is half of the mass of the negative charged particle. The two charges are separated by a distance l. If the dipole is placed in a uniform electric field $\vec{E}$; such a way that dipole axis makes a very small angle with the electric field $\vec{E}$. The angular frequency of the oscillations of the dipole when released is given by:

[6 April, 2023 (Shift-II)]

(a) $\sqrt{\frac{8qqE}{3ml}}$ (b) $\sqrt{\frac{4qE}{ml}}$ (c) $\sqrt{\frac{4qE}{3ml}}$ (d) $\sqrt{\frac{8qE}{ml}}$

64. Given below are two statements:

Statement-I: A point charge is brought in an electric field. The value of electric field at a point near to the charge may increase if the charge is positive.

Statement-II: An electric dipole is placed in a non-uniform electric field. The net electric force on the dipole will not be zero.

Choose the correct answer from the options given below:

[28 June, 2022 (Shift-I)]

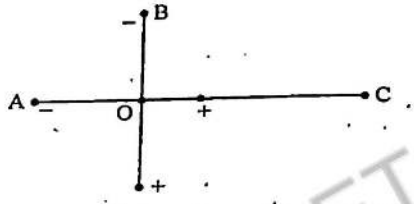
(a) Both Statement-I and Statement-II are true
(b) Both Statement-I and Statement-II are false
(c) Statement-I is true but Statement-II is false
(d) Statement-I is false but Statement-II is True

65. Two electric dipoles of dipole moments 1.2×10^{-30} and 2.4×10^{-3} cm are placed in two different uniform electric fields of strengths 5×10^4 NC^{-1} and 15×10^4 NC^{-1} respectively. The ratio of maximum torque experienced by the electric dipoles will be $\frac{1}{x}$. The value of x is _____. **[28 July, 2022 (Shift-I)]**

66. Two ideal electric dipoles A and B, having their dipole moment p_1 and p_2 respectively are placed on a plane with their centres at O as shown in the figure. At point C on the axis of dipole A, the resultant electric field is making an angle of 37° with the axis.

The ratio of the dipole moment of A and B, $\frac{p_1}{p_2}$ is:

(take $\sin 37^\circ = \frac{3}{5}$) **[25 July, 2021 (Shift-II)]**



(a) $\frac{3}{8}$ (b) $\frac{3}{2}$ (c) $\frac{4}{3}$ (d) $\frac{2}{3}$

67. An electric dipole is placed on $x-$axis in proximity to a line charge of linear density 3.0×10^{-6} C/m. Line charge is placed on $z-$axis and positive and negative charge of dipole is at a distance of 10 mm and 12 mm from the origin respectively. If total force of 4 N is exerted on the dipole, find out the amount of positive charge of the dipole.

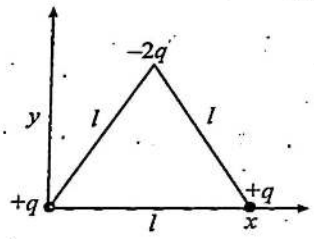
[22 July, 2021 (Shift-II)]

(a) 0.485 mC (b) 8.8 μC (c) 815.1nC (d) 4.44 μC

68. An electric dipole of moment $\vec{p} = (-\hat{i} - 3\hat{j} + 2\hat{k}) \times 10^{-29}$ C.m. is at the origin (0, 0, 0). The electric field due to this dipole at $\vec{r} = (+\hat{i} + 3\hat{j} + 5\hat{k})$ (note that $\vec{r} \cdot \vec{p} = 0$) is parallel to **[9 Jan, 2020 (Shift-I)]**

(a) $\left(+\hat{i} + 3\hat{j} - 2\hat{k}\right)$ (b) $\left(-\hat{i} + 3\hat{j} - 2\hat{k}\right)$
(c) $\left(+\hat{i} - 3\hat{j} - 2\hat{k}\right)$ (d) $\left(-\hat{i} - 3\hat{j} + 2\hat{k}\right)$

69. Determine the electric dipole moment of the system of three charges, placed on the vertices of an equilateral triangle, as shown in the figure **[12 Jan, 2019 (Shift-I)]**



(a) $\sqrt{3}ql\frac{\hat{j}-\hat{i}}{\sqrt{2}}$ (b) $(ql)\frac{\hat{i}+\hat{j}}{\sqrt{2}}$ (c) $2q\hat{i}$ (d) $-\sqrt{3}q\hat{i}$

70. An electric dipole is formed by two equal and opposite charges q with separation d. The charges have same mass m. It is kept in a uniform electric field E. If it is slightly rotated from its equilibrium orientation, then its angular frequency ω is **[8 April, 2019 (Shift-II)]**

(a) $\sqrt{\frac{qE}{2md}}$ (b) $2\sqrt{\frac{qE}{md}}$ (c) $\sqrt{\frac{2qE}{md}}$ (d) $\sqrt{\frac{qE}{md}}$

@FAKE_PAGE_X@RAJ_SIR_NET

Motion of Charged Particle in Uniform Electric Field

71. A particle of charge '$-q$' and mass 'm' moves in a circle of radius 'r' around an infinitely long line charge of linear density '$+\lambda$'. Then time period will be given as: (Consider k as Coulomb's constant)
[30 Jan, 2024 (Shift-II)]

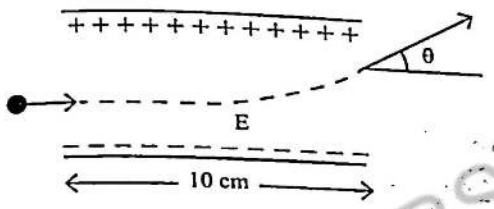
(a) $T^2 = \frac{4\pi m}{2k\lambda q} r^3$ (b) $T = 2\pi r \sqrt{\frac{m}{2k\lambda q}}$

(c) $T = \frac{1}{2\pi r}\sqrt{\frac{m}{2k\lambda q}}$ (d) $T = \frac{1}{2\pi}\sqrt{\frac{2k\lambda q}{m}}$

72. An electron is moving under the influence of the electric field of a uniformly charged infinite plane sheet S having surface charge density $+\sigma$. The electron at t = 0 is at a distance of 1 m from S and has a speed of 1 m/s. The maximum value of σ if the electron strikes S at t = 1 s is $\alpha\left[\frac{m\epsilon_0}{e}\right]\frac{C}{m^2}$ the value of α is

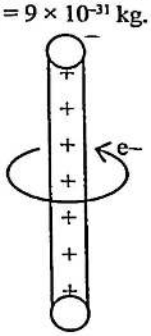
[29 Jan, 2024 (Shift-I)]

73. A uniform electric field of 10 N/C is created between two parallel charged plates (as shown in figure). An electron enters the field symmetrically between the plates with a kinetic energy 0.5eV. The length of each plate is 10 cm. The angle (θ) of deviation of the path of electron as it comes out of the field is (in degree).
[25 Jan, 2023 (Shift-I)]



74. A stream of a positively charged particles having $\frac{q}{m} = 2\times10^{11}\frac{C}{kg}$ and velocity $\vec{v}_0 = 3\times10^7\hat{i}m/s$ is deflected by an electric field $1.8\hat{j}kV/m$. The electric field exists in a region of 10 cm along x direction. Due to the electric field, the deflection of the charge particles in the y direction is _____ mm. [24 Jan, 2023 (Shift-I)]

75. An electron revolves around an infinite cylindrical wire having uniform linear change density 2×10^{-8} cm^{-1} in circular path under the influence of attractive electrostatic field as shown in the figure. The velocity of electron with which it is revolving is _____ $\times 10^6$ ms^{-1}. Given mass of electron = 9×10^{-31} kg. [10 April, 2023 (Shift-II)]

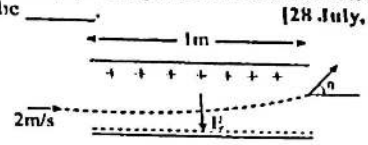


76. A vertical electric field of magnitude 4.9×10^1 N/C just prevents a water droplet of a mass 0.1 g from falling. The value of charge on the droplet will be:
(Given $g = 9.8$ m/s^2) [24 June, 2022 (Shift-I)]

(a) 1.6×10^{-9}C (b) 2.0×10^{-9}C

(c) 3.2×10^{-9}C (d) 0.5×10^{-9}C

77. A uniform electric field $E = (8m/e)$ V/m is created between two parallel plates of length 1 m as shown in figure. (where m = mass of electron and e = charge of electron). An electron enters the field symmetrically between the plates with a speed of 2 m/s. The angle of the deviation (θ) of the path of the electron as it comes out of the field will be _____. [28 July, 2022 (Shift-II)]



(a) $\tan^{-1}(4)$ (b) $\tan^{-1}(2)$ (c) $\tan^{-1}\left(\frac{1}{3}\right)$ (d) $\tan^{-1}(3)$

78. A long cylindrical volume contains a uniformly distributed charge of density ρ. The radius of cylindrical volume is R. A charge particle (q) revolves around the cylinder in a circular path. The kinetic energy of the particle is: [24 June, 2022 (Shift-II)]

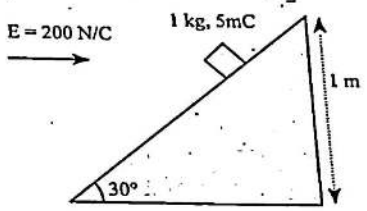
(a) $\frac{\rho qR^2}{4\epsilon_0}$ (b) $\frac{\rho qR^2}{2\epsilon_0}$ (c) $\frac{q\rho}{4\epsilon_0 R^2}$ (d) $\frac{4\epsilon_0 R^2}{q\rho}$

79. A positive charge particle of 100 mg is thrown in opposite direction to a uniform electric field of strength 1×10^5 NC^{-1}. If the charge on the particle is 40 μC and the initial velocity is 200 ms^{-1}, how much distance it will travel before coming to the rest momentarily:
[29 June, 2022 (Shift-I)]

(a) 1 m (b) 5 m (c) 10 m (d) 0.5 m

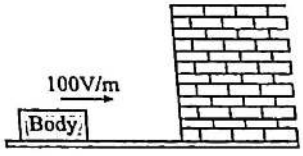
80. An inclined plane making an angle of 30° with the horizontal is placed in a uniform horizontal electric field $200\frac{N}{C}$ as shown in the figure. A body of mass 1 kg and charge 5mC is allowed to slide down from rest at a height of 1m. If the coefficient of friction is 0.2, find the time taken by the body to reach the bottom.
[26 Feb, 2021 (Shift-II)]

$\left[g = 9.8m/s^2; \sin 30^\circ = \frac{1}{2}; \cos 30^\circ = \frac{\sqrt{3}}{2}\right]$



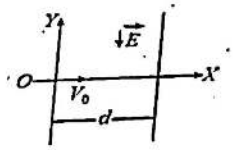
(a) 1.3 s (b) 0.46 s (c) 2.3 s (d) 0.92 s

81. A body having specific charge 8μC/g is resting on a frictionless plane at a distance 10cm from the wall (as shown in the figure). It starts moving towards the wall when a uniform electric field of 100 V/m is applied horizontally towards the wall. If the collision of the body with the wall is perfectly elastic, then the time period of the motion will be _____s. [20 July, 2021 (Shift-I)]



BREAK_CBSE_X_@RAJ_ARORE

82. A charged particle (mass m and charge q) moves along X-axis with velocity V_0. When it passes through the origin it enters a region having uniform electric field $\vec{E} = -E\hat{j}$ which extends upto $x = d$. Equation of path of electron in the region $x > d$ is
[2 Sep, 2020 (Shift-I)]



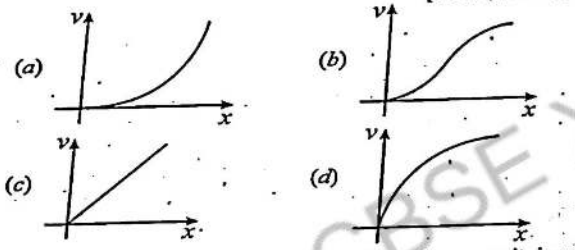
(a) $y = \frac{qEd}{mV_0^2}(x-d)$ (b) $y = \frac{qEd^2}{mV_0^2}x$

(c) $y = \frac{qEd}{mV_0^2}\left(\frac{d}{2}-x\right)$ (d) $y = \frac{qEd}{mV_0^2}x$

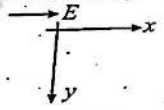
83. A particle of charge q and mass m is subjected to an electric field $E = E_0(1 - ax^2)$ in the x-direction, where a and E_0 are constants. Initially the particle was at rest at $x = 0$. Other than the initial position the kinetic energy of the particle becomes zero when the distance of the particle from the origin is
[4 Sep, 2020 (Shift-II)]

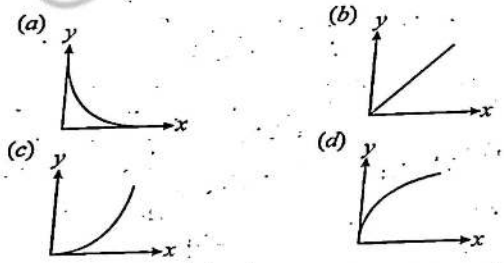
(a) $\sqrt{\frac{3}{a}}$ (b) $\sqrt{\frac{2}{a}}$ (c) $\sqrt{\frac{1}{a}}$ (d) a

84. A particle of mass m and charge q is released from rest in a uniform electric field. If there is no other force on the particle, the dependence of its speed v on the distance x travelled by it is correctly given by (graphs are schematic and not drawn to scale)
[8 Jan, 2020 (Shift-II)]



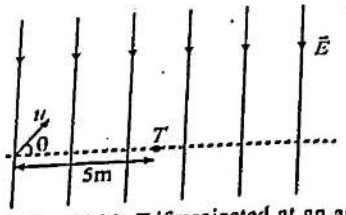
85. A small point mass carrying some positive charge on it, is released from the edge of a table. There is a uniform electric field in this region in the horizontal direction. Which of the following options then correctly describe the trajectory of the mass? (Curves are drawn schematically and are not to scale).
[2 Sep, 2020 (Shift-II)]





86. A uniform electric field, $\vec{E} = -40\sqrt{3}\hat{y}NC^{-1}$ is applied in a region. A charged particle of mass m carrying positive charge q is projected in this region with an initial speed of $2\sqrt{10}\times10^6 ms^{-1}$. This particle is aimed to hit a target T, which is 5 m away from its entry point into the field as shown schematically in the figure. Take $\frac{q}{m} = 10^{10} Ckg^{-1}$.
[JEE Adv, 2020]

Then



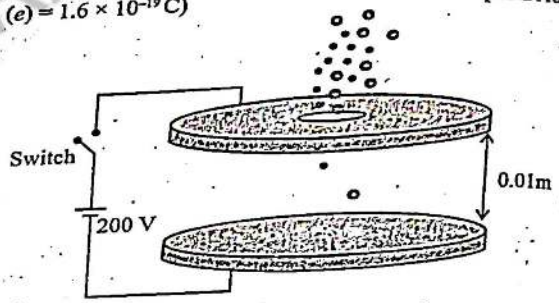
(a) The particle will hit T if projected at an angle 45° from the horizontal

(b) The particle will hit T if projected either at an angle 30° or 60° from the horizontal

(c) Time taken by the particle to hit T could be $\sqrt{\frac{5}{6}}$ μs as well as $\sqrt{\frac{5}{3}}$ μs

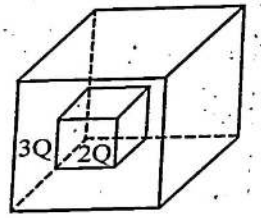
(d) Time taken by the particle to hit T is $\sqrt{\frac{5}{2}}$ μs

87. Two large circular discs separated by a distance of 0.01 m are connected to a battery via a switch as shown in the figure. Charged oil drops of density 900 kg m^{-3} are released through a tiny hole at the center of the top disc. Once some oil drops achieve terminal velocity, the switch is closed to apply a voltage of 200 V across the discs. As a result, an oil drop of radius 8×10^{-7} m stops moving vertically and floats between the discs. The number of electrons present in this oil drop is _____. (Neglect the buoyancy force, take acceleration due to gravity $= 10\ ms^{-2}$ and charge on an electron $(e) = 1.6 \times 10^{-19} C$)
[JEE Adv, 2020]



Gauss Law and Application, Electric Flux

88. C_1 and C_2 are two hollow concentric cubes enclosing charges 2Q and 3Q respectively as shown in figure. The ratio of electric flux passing through C_1 and C_2 is:



[1 Feb, 2024 (Shift-II)]

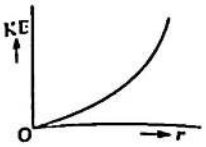
(a) 2 : 5 (b) 5 : 2 (c) 2 : 3 (d) 3 : 2

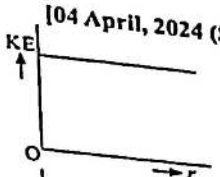
@FAST CBSE X @FAST CBSE

89. An electric field is given by $(6\hat{i} + 5\hat{j} + 3\hat{k})$ N/C. The electric flux through a surface area $30\hat{i}$ m² lying in YZ-plane (in SI unit) is:
[29 Jan, 2024 (Shift-II)]
(a) 90 (b) 150 (c) 180 (d) 60

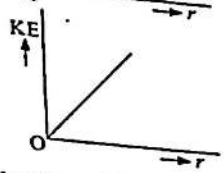
90. Two charges of $5Q$ and $-2Q$ are situated at thepoints $(3a, 0)$ and $(-5a, 0)$ respectively. The electric flux through a sphere of radius '$4a$' having center at origin is:
[29 Jan, 2024 (Shift-I)]
(a) $\frac{2Q}{\varepsilon_0}$ (b) $\frac{5Q}{\varepsilon_0}$ (c) $\frac{7Q}{\varepsilon_0}$ (d) $\frac{3Q}{\varepsilon_0}$

91. An infinitely long positively charged straight thread has a linear charge density λ Cm^{-1}. An electron revolves along a circular path having axis along the length of the wire. The graph that correctly represents the variation of the kinetic energy of electron as a function of radius of circular path from the wire is:
[04 April, 2024 (Shift-I)]

(a) 

(b) 

(c)

(d) 

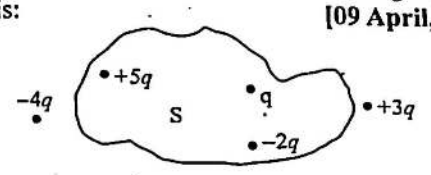
92. An infinite plane sheet of charge having uniform surface charge density $+\sigma_s$ C/m² is placed on x-y plane. Another infinitely long line charge having uniform linear charge density $+\lambda_e$ C/m is placed at $z = 4$m plane and parallel to y-axis. If the magnitude values $|\sigma_s| = 2|\lambda_e|$ then at point $(0, 0, 2)$, the ratio of magnitudes of electric field values due to sheet charge to that of line charge is $\pi\sqrt{n} : 1$.
The value of n is _____.
[04 April, 2024 (Shift-I)]

93. A charge q is placed at the center of one of the surface of a cube. The flux linked with the cube is:
[04 April, 2024 (Shift-II)]
(a) $\frac{q}{4\varepsilon_0}$ (b) $\frac{q}{2\varepsilon_0}$ (c) $\frac{q}{8\varepsilon_0}$ (d) Zero

94. σ is the uniform surface charge density of a thin spherical shell of radius R. The electric field at any point on the surface of the spherical shell is:
[06 April, 2024 (Shift-I)]
(a) $\sigma/\varepsilon_0 R$ (b) $\sigma/2\varepsilon_0$ (c) σ/ε_0 (d) $\sigma/4\varepsilon_0$

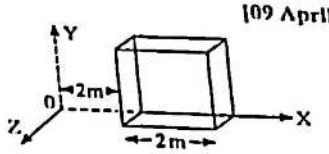
95. An electric field, $\vec{E} = \frac{2\hat{i} + 6\hat{j} + 8\hat{k}}{\sqrt{6}}$ passes through the surface of 4 m² area having unit vector $\hat{n} = \left(\frac{2\hat{i} + \hat{j} + \hat{k}}{\sqrt{6}}\right)$. The electric flux for that surface is _____ V m.
[08 April, 2024 (Shift-I)]

96. Five charges $+q$, $+5q$, $-2q$, $+3q$ and $-4q$ are situated as shown in the figure. The electric flux due to this configuration through the surface S is:
[09 April, 2024 (Shift-II)]



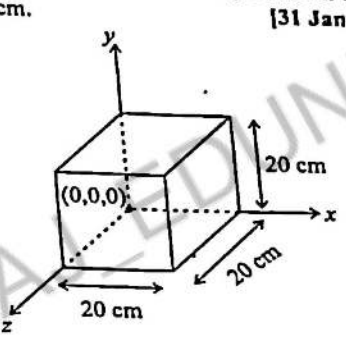
(a) $\frac{5q}{\varepsilon_0}$ (b) $\frac{4q}{\varepsilon_0}$ (c) $\frac{3q}{\varepsilon_0}$ (d) $\frac{q}{\varepsilon_0}$

97. An electric field $\vec{E} = 2x\hat{i}\ NC^{-1}$ exists in space. A cube of side 2 m is placed in the space as per figure given below. The electric flux through the cube is ..... Nm²/C.
[09 April, 2024 (Shift-II)]



98. In a cuboid of dimension $2l \times 2l \times l$, a charge q is placed at the centre of the surface 'S' having area of $4l^2$. The flux through the opposite surface to 'S' is given by
[29 Jan, 2023 (Shift-I)]
(a) $\frac{q}{12\varepsilon_0}$ (b) $\frac{q}{3\varepsilon_0}$ (c) $\frac{q}{2\varepsilon_0}$ (d) $\frac{q}{6\varepsilon_0}$

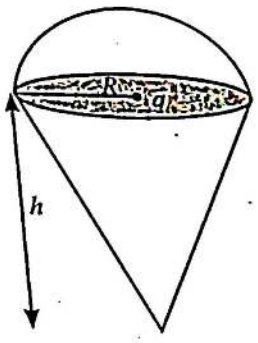
99. Expression for an electric field is given by $\vec{E} = 4000x^2\hat{i}\frac{V}{m}$. The electric flux through the cube of side 20 cm when placed in electric field (as shown in the figure) is _____ V cm.
[31 Jan, 2023 (Shift-I)]



100. If a charge q is placed at the center of a closed hemi-spherical non-conducting surface, the total flux passing through the flat surface would be
[27 June, 2022 (Shift-II)]

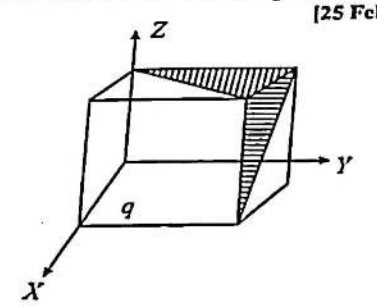
(a) $\frac{q}{\epsilon_0}$ (b) $\frac{q}{2\epsilon_0}$ (c) $\frac{q}{4\epsilon_0}$ (d) $\frac{q}{2\pi\epsilon_0}$

101. A charge q is surrounded by a closed surface consisting of an inverted cone of height h and base radius R, and a hemisphere of radius R as shown in the figure. The electric flux through the conical surface is $\frac{nq}{6\epsilon_0}$ (in SI units). The value of n is _____.
[JEE Adv, 2022]



@FKE_OBSEK @RAKEDUNET

102. A charge 'q' is placed at one corner of a cube as shown in figure. The flux of electrostatic field E though the shaded area is:
[25 Feb, 2021 (Shift-II)]

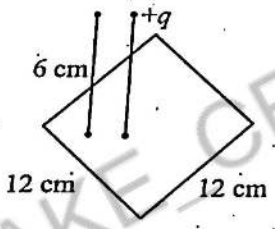


(a) $\frac{q}{48\epsilon_0}$ (b) $\frac{q}{8\epsilon_0}$ (c) $\frac{q}{24\epsilon_0}$ (d) $\frac{q}{4\epsilon_0}$

103. Given below are two statements:
Statement-I: An electric dipole is placed at the center of a hollow sphere. The flux of electric field through the sphere is zero but the electric field is not zero anywhere in the sphere.
Statement-II: If R is the radius of a solid metallic sphere and Q be the total charge on it. The electric field at any point on the spherical surface of radius $r(<R)$ is zero but the electric flux passing through this closed spherical surface of radius r is not zero.
In the light of the above statements. Choose the correct answer from the option given below: **[26 Feb, 2021 (Shift-II)]**

(a) Statement-I is true but Statement-II is false
(b) Statement-I is false but Statement-II is true
(c) Both Statement-I and Statement-II are true
(d) Both Statement-I and Statement-II are false

104. A point charge of + 12μC is at a distance 6 cm vertically above the centre of a squared of side 12 cm as shown in figure. The magnitude of the electric flux through the square will be _____ $\times 10^3$ Nm²/C. **[24 Feb, 2021 (Shift-II)]**



105. The total charge enclosed in an incremental volume of 2×10^{-9}m³ located at the origin is _____nC, if electric flux density of its field is found as **[22 July, 2021 (Shift-II)]**

$\vec{D} = e^{-x}\sin y\hat{i} - e^{-x}\cos y\hat{j} + 2z\hat{k}\ C/m^2$

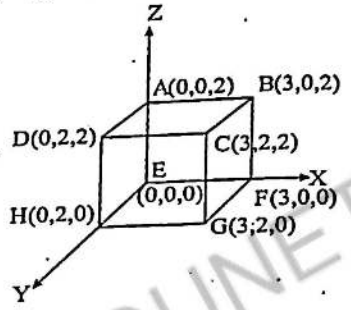
106. The electric field in a region is given by

$\vec{E} = \left(\frac{3}{5}E_0\hat{i} + \frac{4}{5}E_0\hat{j}\right)\frac{N}{c}$. The ratio of flux of reported field through the rectangular surface of area 0.2 m² (parallel to $y-z$ plane) to that of the surface of area 0.3 m² (parallel to $x-z$ plane) is $a:b$, where $a =$ _____ (round off to nearest integer) [Here $\hat{i}$, $\hat{j}$ and $\hat{k}$ are unit vectors along x, y and z-axes respectively] **[25 Feb, 2021 (Shift-I)]**

107. The electric field in a region is given by

$\vec{E} = \frac{2}{5}E_0\hat{i} + \frac{3}{5}E_0\hat{j}$ with $E_0 = 4.0 \times 10^3\frac{N}{C}$. The flux of this field through a rectangular surface area 0.4 m² parallel to the $Y-Z$ plane is _____ Nm^2C^{-1} **[17 March, 2021 (Shift-II)]**

108. An electric field $\vec{E} = 4x\hat{i} - (y^2+1)\hat{j}$ N/C passes through the box shown in figure. The flux of the electric field through surface $ABCD$ and $BCGF$ and marked as ϕ_I and ϕ_{II} respectively. The difference between $(\phi_I - \phi_{II})$ is (in Nm^2/C) **[9 Jan, 2020 (Shift-II)]**



109. A circular disc of radius R carries surface charge density $\sigma(r) = \sigma_0\left(1 - \frac{r}{R}\right)$, where σ_0 is a constant and r is the distance from the center of the disc. Electric flux through a large spherical surface that encloses the charged disc completely is ϕ_0. Electric flux through another spherical surface of radius $\frac{R}{4}$ and concentric with the disc is ϕ. Then the ratio $\frac{\phi_0}{\phi}$ is ..... **[JEE Adv, 2020]**

110. A charged shell of radius R carries a total charge Q. Given ϕ as the flux of electric field through a closed cylindrical surface of height h, radius r and with its center same as that of the shell. Here, center of the cylinder is a point on the axis of the cylinder which is equidistant from its top and bottom surfaces. Which of the following option(s) is/are correct? [ε_0 is the permittivity of free space] **[JEE Adv, 2019]**

(a) If $h > 2R$ and $r > R$ then $\Phi = \frac{Q}{\varepsilon_0}$

(b) If $h < \frac{8R}{5}$ and $r = \frac{3R}{5}$ then $\Phi = 0$

(c) If $h > 2R$ and $r = \frac{4R}{5}$ then $\Phi = \frac{Q}{5\varepsilon_0}$

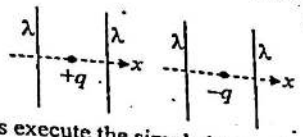
(d) If $h > 2R$ and $r = \frac{3R}{5}$ then $\Phi = \frac{Q}{5\varepsilon_0}$

@JEE_OBSE_X@RAJEDUNET

Coulomb Force

Single Correct

1. The figures below depict two situations in which two infinitely long static line charges of constant positive line charge density λ are kept parallel to each other. In there resulting electric field, point charges q and $-q$ are kept in equilibrium between them. The point charges are confined to moving in the x direction only. If they are given a small displacement about their equilibrium positions, then the correct statement is/are **(JEE Adv. 2015)**



(a) Both charges execute the simple harmonic motion
(b) Both charges will continue moving in the direction of their displacement
(c) Charge $+q$ executes simple harmonic motion while charge $-q$ continues moving in the direction of its displacement
(d) Charge $-q$ executes simple harmonic motion while charge $+q$ continues moving in the direction of its displacement

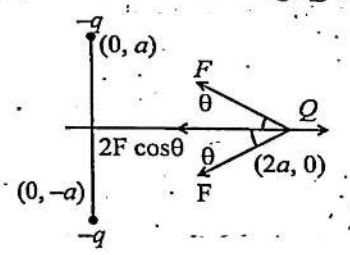
2. A tiny spherical oil drop carrying a net charge q is balanced in still air with a vertical uniform electric field of strength $\frac{81\pi}{7}\times10^5$ Vm^{-1}. When the field is switched off, the drop is observed to fall with terminal velocity 2×10^{-3} ms^{-1}. Given $g = 9.8$ ms^{-2}, viscosity of the air $= 1.8\times10^{-5}$ Ns m^{-2} and the density of oil $= 900$ kg m^{-3}, the magnitude of q is **(IIT-JEE 2010)**

(a) $1.6\times10^{-19}\,C$ (b) $3.2\times10^{-19}\,C$
(c) $4.8\times10^{-19}\,C$ (d) $8.0\times10^{-19}\,C$

3. A charge q is placed at the centre of the line joining two equal charges Q. The system of the three charges will be in equilibrium if q is equal to **(IIT-JEE 1987)**

(a) $-\frac{Q}{2}$ (b) $-\frac{Q}{4}$ (c) $+\frac{Q}{4}$ (d) $+\frac{Q}{2}$

4. Two equal negative charges $-q$ are fixed at points $(0, -a)$ and $(0, a)$ on y-axis. A positive charge Q is released from rest at the point $(2a, 0)$ on the x-axis. The charge Q will **(IIT-JEE 1984)**



(a) Execute simple harmonic motion about the origin
(b) Move to the origin and remain at rest
(c) Move to infinity
(d) Execute oscillatory but not simple harmonic motion

Multiple Correct

5. A disk of radius R with uniform positive charge density σ is placed on the xy plane with its center at the origin. The Coulomb potential along the z-axis is $V(z)=\frac{\sigma}{2\epsilon_0}(\sqrt{R^2+z^2}-z)$

A particle of positive charge q is placed initially at rest at a point on the z axis with $z = z_0$ and $z_0 > 0$. In addition to the Coulomb force, the particle experiences a vertical force $\vec{F}=-c\hat{k}$ with $c > 0$. Let $\beta=\frac{2c\epsilon_0}{q\sigma}$. Which of the following statements is/are correct?

C-1.11 W-11.75 UA-69.43 (JEE Adv. 2022)

(a) For $\beta=\frac{1}{4}$ and $z_0=\frac{25}{7}R$, the particle reaches the origin
(b) For $\beta=\frac{1}{4}$ and $z_0=\frac{3}{7}R$, the particle reaches the origin
(c) For $\beta=\frac{1}{4}$ and $z_0=\frac{R}{\sqrt{3}}$, the particle returns back to $z = z_0$
(d) For $\beta > 1$ and $z_0 > 0$, the particle always reaches the origin

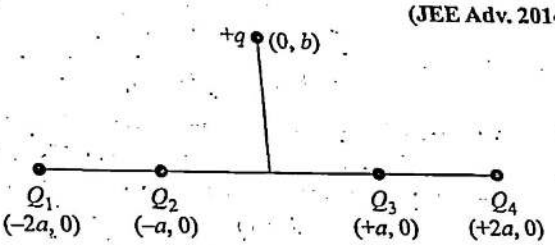
6. Two identical non-conducting solid spheres of same mass and charge are suspended in air from a common point by two non-conducting, massless strings of same length. At equilibrium, the angle between the strings is α. The spheres are now immersed in a dielectric liquid of density 800 kg/m^3 and dielectric constant 21. If the angle between the strings remains the same after the immersion, then

C-19.64 W-35.76 UA-26.62 PC-17 (JEE Adv. 2020)

(a) electric force between the spheres remains unchanged
(b) electric force between the spheres reduces
(c) mass density of the spheres is 840 kg m^{-3}
(d) the tension in the strings holding the spheres remains unchanged

Match the Column

7. Four charges Q_1, Q_2, Q_3 and Q_4 of same magnitude are fixed along the x-axis at $x = -2a, -a, +a$ and $+2a$ respectively. A positive charge q is placed on the positive y-axis at a distance $b > 0$. Four options of the signs of these charges are given in List-I. The direction of the forces on the charge q is given in List-II. Match List-I with List-II and select the correct answer using the code given below the lists. **(JEE Adv. 2014)**



@FAST_CBSE_X_TO_XII_EDUNET

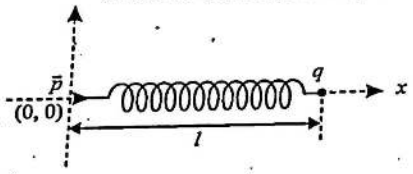
List-I		List-II	
P.	Q_1, Q_2, Q_3, Q_4 all positive	1.	$+x$
Q.	Q_1, Q_2 positive, Q_3, Q_4 negative	2.	$-x$
R.	Q_1, Q_4 positive Q_2, Q_3 negative	3.	$+y$
S.	Q_1, Q_3 positive Q_2, Q_4 negative	4.	$-y$

(a) P-3, Q-1, R-4, S-2 (b) P-4, Q-2, R-3, S-1
(c) P-3, Q-1, R-2, S-4 (d) P-4, Q-2, R-1, S-3

Numerical Types

8. One end of a spring of negligible unstretched length and spring constant k is fixed at the origin (0, 0) A point particle of mass m carrying a positive charge q is attached at its other end. The entire system is kept on a smooth horizontal surface. When a point dipole $\vec{p}$ pointing towards the charge q is fixed at the origin, the spring gets stretched to a length l and attains a new equilibrium position (see figure below). If the point mass is now displaced slightly by $\Delta l << l$ from its equilibrium position and released, it is found to oscillate at frequency $\frac{1}{\delta}\sqrt{\frac{k}{m}}$. The value of δ is _____

C-3.88 W-70.36 UA-25.75 (JEE Adv. 2020)



9. A small ball of mass 2×10^{-3} kg having a charge of $1\mu C$ is suspended by a string of length 0.8 m. Another identical ball having the same charge is kept at the point of suspension. Determine the minimum horizontal velocity which should be imparted to the lower ball, so that it can make complete revolution. (IIT-JEE 2001)

True/False

10. A ring of radius R carries a uniformly distributed charge $+Q$. A point charge $-q$ is placed on the axis of the ring at a distance $2R$ from the center of the ring and released from rest. The particle executes a simple harmonic motion along the axis of the ring. (IIT-JEE 1988)

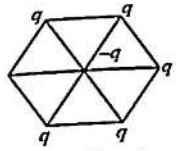
Subjective

11. Three particles, each of mass 1 g and carrying a charge q, are suspended from a common point by insulated massless string, each 100 cm long. If the particles are in equilibrium and are located at the corners of an equilateral triangle of side length 3 cm, calculate the charge q on each particle.
(Take $g = 10$ m/s^2) (IIT-JEE 1988)

12. A pendulum bob of mass 80 mg and carrying a charge of 2×10^{-8} C is at rest in a horizontal uniform electric field of 20,000 V/m. Find the tension in the thread of the pendulum and the angle it makes with the vertical. (Take $g = 9.8$ ms^{-2}) (IIT-JEE 1979)

Fill in the Blanks

13. Five point charges, each of value $+q$ coulomb, are placed on five vertices of a regular hexagon of side L metre. The magnitude of the force on the point charge of value $-q$ coulomb placed at the centre of the hexagon .....newton. (IIT-JEE 1992)



14. Two small balls having equal positive charges Q (coulomb) on each are suspended by two insulating strings of equal length L (metre) from a hook fixed to a stand. The whole setup is taken in a satellite into space where there is no gravity (state of weightlessness). The angle between the strings is ..... and the tension in each string is .....newton. (IIT-JEE 1986)

Match the Column

15. The electric field E is measured at a point $P(0, 0, d)$ generated due to various charge distributions and the dependence of E and d is found to be difference for different charge distributions. List-I contains different relations between E and d. List-II describes different electric charge distributions, along with their locations. Match the functions in List-I with the related charge distributions in List-II. (JEE Adv. 2018)

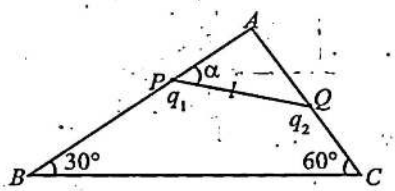
List-I	List-II
P. E is independent of d.	1. A point charge Q at the origin.
Q. E is proportional to $\frac{1}{d^2}$	2. A small dipole with point charges Q at (0, 0, 1) and $-Q$ at (0, 0, −1) take $2l << d$.
R. E is proportional of $\frac{1}{d^2}$.	3. An infinite line charge coincident with x-axis with uniform linear charge Density λ.
S. E is proportional of $\frac{1}{d^2}$.	4. Two infinite wires carrying a linear charge density parallel to x-axis.
P. E is independent of d.	5. Infinite plane charge coincident with x-y plane with uniform surface.

(a) $P \to 5; Q \to 3, 4; R \to 1; S \to 2$
(b) $P \to 5; Q \to 3; R \to 1, 4; S \to 2$
(c) $P \to 5; Q \to 3; R \to 1, 2; S \to 4$
(d) $P \to 4; Q \to 2, 3; R \to 1; S \to 5$

Subjective

16. A charged particle is free to move in an electric field. Will it always move along an electric line of force? (IIT-JEE 1979)

17. A rigid insulated wire frame in the form of a right angled triangle ABC, is set in a vertical plane as shown in figure. Two beads of equal masses m each and carrying charges q_1 and q_2 are connected by a cord of length l and can slide without friction on the wires. Considering the case when the beads are stationary determine (IIT-JEE 1978)



© WWW.CSEA@RAJ...

(a) (i) The angle α
(ii) The tension in the cord
(iii) The normal reaction on the beads

(b) If the cord is now cut what are the value of the charges for which the beads continue to remain stationary?

Electric Field and Field Lines

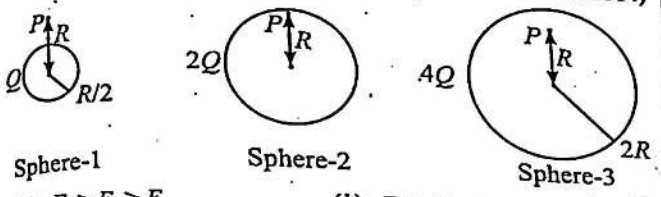
Single Correct

18. Let $E_1(r)$, $E_2(r)$ and $E_3(r)$ be the respective electric fields at a distance r from a point charge Q, an infinitely long wire with constant linear charge density λ, and an infinite plane with uniform surface charge density σ. If $E_1(r_0) = E_2(r_0) = E_3(r_0)$ at a given distance r_0, then **(JEE Adv. 2014)**

(a) $Q = 4\sigma\pi r_0^2$ (b) $r_0 = \dfrac{\lambda}{2\pi\sigma}$

(c) $E_1(r_0/2) = 2E_2(r_0/2)$ (d) $E_2(r_0/2) = 4E_3(r_0/2)$

19. Charges Q, $2Q$ and $4Q$ are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii $\dfrac{R}{2}$, R and $2R$ respectively, as shown in figure. If magnitudes of the electric fields at point P at a distance R from the centre of spheres 1, 2 and 3 are E_1, E_2, and E_3 respectively, then **(JEE Adv. 2014)**

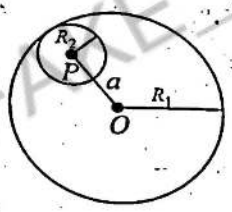


Sphere-1 Sphere-2 Sphere-3

(a) $E_1 > E_2 > E_3$ (b) $E_3 > E_1 > E_2$

(c) $E_2 > E_1 > E_3$ (d) $E_3 > E_2 > E_1$

20. Consider a uniform spherical charge distribution of radius R_1 centered at the origin O. In this distribution, a spherical cavity of radius R_2, centered at P with distance $OP = a = R_1 - R_2$ (see figure) is made.



If the electric field inside the cavity at position r is $E(r)$, then the correct statements is/are **(IIT-JEE 2011)**

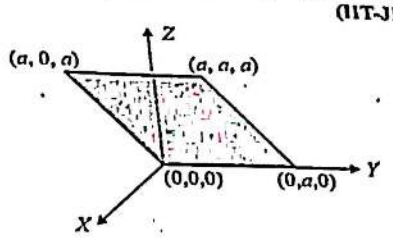
(a) E is uniform, its magnitude is independent of R_2 but its direction depends on r

(b) E is uniform, its magnitude depends on R_2 and its direction depends on r

(c) E is uniform, its magnitude is independent of 'a' but its direction depends on a

(d) E is uniform and both its magnitude and direction depend on a

21. Consider an electric field $E = E_0x$, where E_0 is a constant. The flux through the shaded area (as shown in the figure) due to this field is **(IIT-JEE 2011)**



(a) $2E_0a^2$ (b) $\sqrt{2}E_0a^2$

(c) E_0a^2 (d) $\dfrac{E_0a^2}{\sqrt{2}}$

22. Three concentric metallic spherical shells of radii R, $2R$ and $3R$ are given charges Q_1, Q_2 and Q_3, respectively. It is found that the surface charge densities on the outer surfaces of the shells are equal. Then, the ratio of the charges given to the shells, $Q_1 : Q_2 : Q_3$, is **(IIT-JEE 2009)**

(a) 1 : 2 ; 3 (b) 1 : 3 : 5

(c) 1 : 4 : 9 (d) 1 : 8 : 18

23. Two point charges $+q$ and $-q$ are held fixed at $(-d, 0)$ and $(d, 0)$ respectively of a $x-y$ co-ordinate system. Then **(IIT-JEE 1995)**

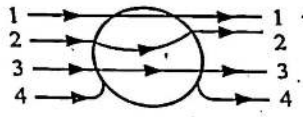
(a) the electric field E at all points on the x-axis has the same direction.

(b) work has to be done in bringing a test charge from ∞ to the origin.

(c) electric field at all point on y-axis is along x-axis.

(d) the dipole moment is $2qd$ along the x-axis.

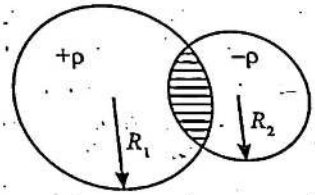
24. A metallic solid sphere is placed in a uniform electric field. The lines of force follow the path(s) shown in figure as **(IIT-JEE 1996)**



(a) 1 (b) 2 (c) 3 (d) 4

Multiple Correct

25. Two non-conducting spheres of radii R_1 and R_2 and carrying uniform volume charge densities $+\rho$ and $-\rho$, respectively, are placed such that they partially overlap, as shown in the figure. At all points in the overlapping region **(JEE Adv. 2013)**



(a) the electrostatic field is zero.

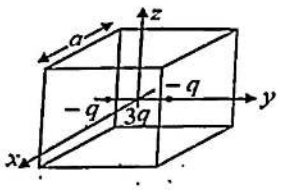
(b) the electrostatic potential is constant.

(c) the electrostatic field is constant in magnitude.

(d) the electrostatic field has same direction.

@FAKE_CASE X @RANDOM

26. A cubical region of side a has its centre at the origin. It encloses three fixed point charges, $-q$ at $(0, -a/4, 0)$, $+3q$ at $(0, 0, 0)$ and $-q$ at $(0, +a/4, 0)$ **(IIT-JEE 2011)**



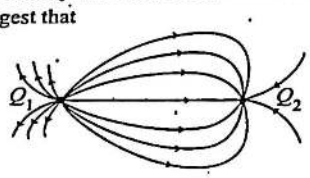
(a) The net electric flux crossing the plane $x = +a/2$ is equal to the net electric flux crossing the plane $x = -a/2$

(b) The net electric flux crossing the plane $y = +a/2$ is more than the net electric flux crossing the plane $y = -a/2$

(c) The net electric flux crossing the entire region is q/ε_0

(d) The net electric flux crossing the plane $z = +a/2$ is equal to the net electric flux crossing the plane $x = +a/2$

27. A few electric field lines for a system of two charges Q_1 and Q_2 fixed at two different points on the x-axis are shown in the figure. These lines suggest that **(IIT-JEE 2010)**



(a) $|Q_1| > |Q_2|$

(b) $|Q_1| < |Q_2|$

(c) at a finite distance to the left of Q_1 the electric field is zero

(d) at a finite distance to the right of Q_2 the electric field is zero

28. A non-conducting solid sphere of radius R is uniformly charged. The magnitude of the electric field due to the sphere at a distance r from its centre **(IIT-JEE 1998)**

(a) increases as r increases for $r < R$

(b) decreases as r increases for $0 < r < \infty$

(c) decreases as r increases for $R < r < \infty$

(d) is discontinuous at $r = R$

29. A positively charged thin metal ring of radius R is fixed in the x–y plane with its centre at the origin O. A negatively charged particle P is released from rest at the point $(0, 0, z_0)$ where $z_0 > 0$. Then the motion of P is **(IIT-JEE 1998)**

(a) periodic for all values of z_0 satisfying $0 < z_0 < \infty$

(b) simple harmonic for all values of z_0 satisfying $0 < z_0 \le R$

(c) approximately simple harmonic provided $z_0 << R$

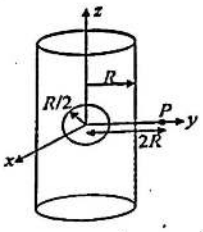
(d) such that P crosses O and continues to move along the negative z-axis towards $z = -\infty$

True/False

30. A small metal ball is suspended in a uniform electric field with the help of an insulated thread. If high energy X-ray beam falls on the ball, the ball will be deflected in the direction of the field. **(IIT-JEE 1983)**

Numerical Types

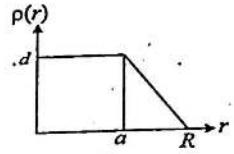
31. An infinitely long solid cylinder of radius R has a uniform volume charge density ρ. It has a spherical cavity of radius $R/2$ with its centre on the axis of the cylinder, as shown in the figure. The magnitude of the electric field at the point P, which is at a distance $2R$ from the axis of the cylinder, is given by the expression $\frac{23\rho R\hat{j}}{16k\epsilon_0}$. The value of k is **(IIT-JEE 2012)**



Gauss's Law and Application

Single Correct

32. The nuclear charge (Ze) is non-uniformly distributed with in a nucleus of radius R. The charge density $p(r)$ (charge per unit volume) is dependent only on the radial distance r from the center of the nucleus as shown in figure. The electric field is only along the radial direction. **(IIT-JEE 2008)**

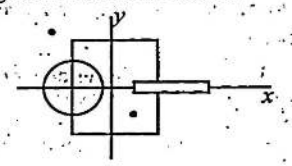


The electric field at $r = R$ is

(a) Independent of a (b) Directly proportional to a

(c) Directly proportional to a^2 (d) Inversely proportional to a

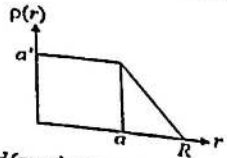
33. A disc of radius $\frac{a}{4}$ having a uniformly distributed charge $6C$ is placed in the x-y plane with its centre at $\left(\frac{-a}{2}, 0, 0\right)$. A rod of length a carrying a uniformly distributed charge $8C$ is placed on the x-axis from $x = \frac{a}{4}$ to $x = \frac{5a}{4}$. Two point charges $-7C$ and $3C$ are placed at $\left(\frac{a}{4}, \frac{-a}{4}, 0\right)$ and $\left(\frac{-3a}{4}, \frac{3a}{4}, 0\right)$, respectively. Consider a cubical surface formed by six surfaces $x = \pm\frac{a}{2}$, $y = \pm\frac{a}{2}$, $z = \pm\frac{a}{2}$. The electric flux through this cubical surface is **(IIT-JEE 2009)**



(a) $\frac{-2}{\varepsilon_0}C$ (b) $\frac{2}{\varepsilon_0}C$ (c) $\frac{10}{\varepsilon_0}C$ (d) $\frac{12}{\varepsilon_0}C$

@FAKE_CBSE_X @FREEJEENET

34. The nuclear charge (Ze) is non-uniformly distributed with a nucleus of radius R. The charge density $\rho(r)$ (charge per unit volume) is dependent only on the radial distance r from the center of the nucleus as shown in figure. The electric field is only along the radial direction. **(IIT-JEE 2008)**



For $a = 0$, the value of d (maximum value of ρ as shown in the figure) is

(a) $\frac{3Re}{4\pi R^3}$ (b) $\frac{3Ze}{\pi R^3}$ (c) $\frac{4Ze}{3\pi R^3}$ (d) $\frac{2e}{3\pi R^3}$

Multiple Correct

35. A charged shell of radius R carries a total charge Q. Given ϕ as the flux of electric field through a closed cylindrical surface of height h, radius r and with its center same as that of the shell. Here, center of the cylinder is a point on the axis of the cylinder which is equidistant from its top and bottom surfaces. Which of the following option(s) is/are correct? [ε_0 is the permittivity of free space]

C-4 W-15 UA-39 PC-41 (JEE Adv. 2019)

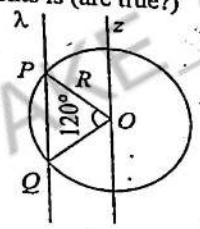
(a) If $h > 2R$ and $r > R$ then $\phi = \frac{Q}{\varepsilon_0}$

(b) If $h < \frac{8R}{5}$ and $r = \frac{3R}{5}$ then $\phi = 0$

(c) If $h > 2R$ and $r = \frac{4R}{5}$ then $\phi = \frac{Q}{5\varepsilon_0}$

(d) If $h > 2R$ and $r = \frac{3R}{5}$ then $\phi = \frac{Q}{5\varepsilon_0}$

36. An infinitely long thin non-conducting wire is parallel to the Z-axis and carries a uniform line charge density λ. It pierces a thin non-conducting spherical shell of radius R in such a way that the arc PQ subtends and angle 120° at the centre O of the spherical shell, as shown in the figure. The permittivity of free space is ε_0. Which of the following statements is (are true?) **(JEE Adv. 2018)**



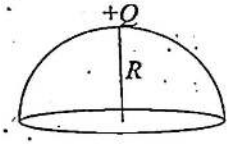
(a) The electric flux through the shell is $\sqrt{3}R\lambda/\varepsilon_0$

(b) The z-component of the electric field is zero at all the points on the surface of the shell

(c) The electric flux through the shell is $\sqrt{2}R\lambda/\varepsilon_0$

(d) The electric field is normal to the surface of the shell at all points

37. A point charge $+Q$ is placed just outside an imaginary hemispherical surface of radius R as shown in the figure. Which of the following statements is/are correct **(JEE Adv. 2017)**



(a) The electric flux passing through the curved surface of the hemisphere is $-\frac{Q}{2\epsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$

(b) The component of the electric field normal to the flat surface is constant over the surface

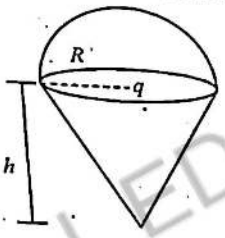
(c) Total flux through the curved and flat surface is $\frac{Q}{\epsilon_0}$

(d) The circumference of the flat surface is an equipotential.

Numerical Types

38. A charge q is surrounded by a closed surface consisting of an inverted cone of height h and base radius R, and a hemisphere of radius R as shown in the figure. The electric flux through the conical surface is $\frac{nq}{6\epsilon_0}$ (in SI units). The value of n is _____.

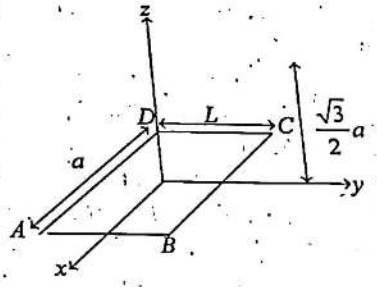
C-15.3 W-69.91 UA-14.79 (JEE Adv. 2022)



39. A circular disc of radius R carries surface charge density $\sigma(r) = \sigma_0\left(1-\frac{r}{R}\right)$, where σ_0 is a constant and r is the distance from the center of the disc. Electric flux through a large spherical surface that encloses the charged disc completely is ϕ_0. Electric flux through another spherical surface of radius $\frac{R}{4}$ and concentric with the disc is ϕ. Then the ratio $\frac{\phi_0}{\phi}$ is .....

C-15.3 W-69.91 UA-14.79 (JEE Adv. 2020)

40. An infinitely long uniform line charge distribution of charge per unit length λ lies parallel to the y-axis in the y-z plane at $z = \frac{\sqrt{3}}{2}a$. (see figure). If the magnitude of the flux of the electric field through the rectangular surface $ABCD$ lying in the x-y plane with its centre at the origin is $\frac{\lambda L}{n\varepsilon_0}$ (ε_0 = permittivity of free space), then the value of n is **(JEE Adv. 2015)**



41. A solid sphere of radius R has a charge Q distributed in its volume with a charge density $\rho = kr^a$, where k and a are constants and r is the distance from its centre. If the electric field at $r = \frac{R}{2}$ is $\frac{1}{8}$ times that at $r = R$, find the value of a **(IIT-JEE 2009)**

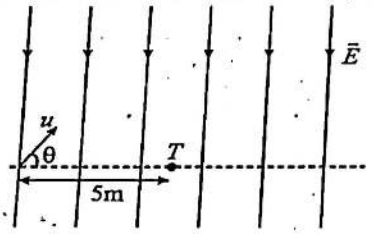
@FAST_CODEX @RAJ_EDUNET

Motion of Charged Particle in Uniform Electric Field

Multiple Correct

42. A uniform electric field, $\vec{E} = -400\sqrt{3}\hat{y}NC^{-1}$ is applied in a region. A charged particle of mass m carrying positive charge q is projected in this region with an initial speed of $2\sqrt{10}\times10^6 ms^{-1}$. This particle is aimed to hit a target T, which is 5 m away from its entry point into the field as shown schematically in the figure. Take $\frac{q}{m} = 10^{10} Ckg^{-1}$.

Then C-35.66 W-20.44 UA-36.47 PC-7.43 (JEE Adv. 2020)



(a) The particle will hit T if projected at an angle 45° from the horizontal

(b) The particle will hit T if projected either at an angle 30° or 60° from the horizontal

(c) Time taken by the particle to hit T could be $\sqrt{\frac{5}{6}}$ μs as well as $\sqrt{\frac{5}{3}}$ μs

(d) Time taken by the particle to hit T is $\sqrt{\frac{5}{2}}$ μs

43. An electron of mass m_e, initially at rest, moves through a certain distance in a uniform electric field in time t_1. A proton of mass m_p, also, initially at rest, takes time t_2 to move through an equal distance in this uniform electric field. Neglecting the effect of gravity, the ratio t_2/t_1 is nearly equal to (IIT-JEE 1997)

(a) 1 (b) $(m_p/m_e)^{1/2}$ (c) $(m_p/m_e)^{1/2}$ (d) 1836

Numerical Types

44. A particle of mass 10^{-3} kg and charge 1.0 C is initially at rest. At time $t = 0$, the particle comes under the influence of an electric field $E(t) = E_0 \sin\omega t\,\hat{i}$, where $E_0 = 1.0\,NC^{-1}$ and $\omega = 10^3$ rad s^{-1}. Consider the effect of only the electrical force on the particle. Then the maximum speed in ms^{-1}, attained by the particle at subsequent time is ..... (JEE Adv. 2019)

True/False

45. An electric line of force in the x-y plane is given by the equation $x^2 + y^2 = 1$. A particle with unit positive charge, initially at rest at the point $x = 1, y = 0$ in the x-y plane, will move along the circular line of force. (IIT-JEE 1988)

@RKE_CBSE X @RKJEEDUNIA

ANSWER KEY

JEE-Main

1. (b)	2. [3]	3. [2]	4. [3]	5. [3]	6. (a)	7. (b)	8. (a)	9. (b)	10. [5440]
11. [300]	12. [2]	13. [24]	14. (a)	15. (b)	16. (d)	17. (a)	18. (b)	19. (d)	20. [17]
21. (a,c,d)	22. (b)	23. (c)	24. (d)	25. (c)	26. [20]	27. [6000]	28. [36]	29. (a)	30. [12]
31. (c)	32. (a,c)	33. (c)	34. (a)	35. (b)	36. (c)	37. (b,d)	38. (c)	39. [5]	40. (a)
41. (b)	42. [6]	43. (b)	44. (c)	45. (a)	46. [24]	47. (a)	48. (b)	49. (a)	50. (a)
51. (a)	52. (c)	53. (d)	54. (a)	55. (a)	56. (a)	57. (b)	58. (d)	59. [2.00]	60. [16]
61. (c)	62. (b)	63. (*)	64. (a)	65. [6]	66. (d)	67. (d)	68. (a)	69. (d)	70. (c)
71. (b)	72. [8]	73. [45]	74. [2]	75. [8]	76. (b)	77. (b)	78. (a)	79. (d)	80. (a)
81. [1]	82. (c)	83. (a)	84. (d)	85. (b)	86. (b,c)	87. [6]	88. (a)	89. (c)	90. (b)
91. (2)	92. (16)	93. (b)	94. (2)	95. [12]	96. (b)	97. (16)	98. (d)	99. [640]	100. (*)
101. [3]	102. (c)	103. (a)	104. [226]	105. [4]	106. [1]	107. [640]	108. [–48]	109. [6.40]	110. (a,b,d)

JEE-Advanced

1. (c)	2. (d)	3. (b)	4. (d)	5. (a, c, d)	6. (b, c)	7. (a)	8. [3.14]	9. [5.86]	10. [False]
15. (b)	18. (c)	19. (c)	20. (d)	21. (c)	22. (b)	23. (c)	24. (d)	25. (c, d)	26. (a, c)
27. (a, d)	28. (a, c)	29. (a, c)	30. [True]	31. [6]	32. (a)	33. (a)	34. (b)	35. (a, b, d)	36. (a, b)
37. (a, d)	38. [3]	39. [6.40]	40. [6]	41. [2]	42. (b, c)	43. (c)	44. [2]	45. [False]	

EXPLANATIONS

JEE-Main

1. (b) In air, force is $F=\frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r_2}$

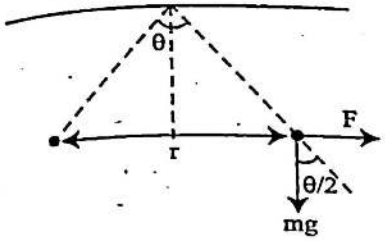
In medium

$$F'=\frac{1}{4\pi(K\epsilon_0)}\frac{q_1q_2}{(r')^2}=\frac{25}{4\pi(5\epsilon_0)}\frac{q_1q_2}{(r)^2}=5F$$

(Take density of water = 1 g/cc)

2. [3] In air,

$$\tan\frac{\theta}{2}=\frac{F}{mg}=\frac{q^2}{4\pi\epsilon_0 r^2 mg} \quad ...(i)$$



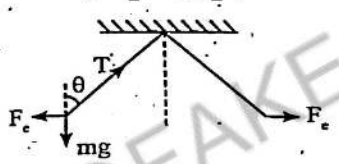
In water,

$$\tan\frac{\theta}{2}=\frac{F'}{mg'}=\frac{q^2}{4\pi\epsilon_0\epsilon_r r^2 mg_{eff}} \quad ...(ii)$$

Equating, both equations

$$\Rightarrow \epsilon_0 g=\epsilon_0\epsilon_r g\left[1-\frac{1}{1.5}\right]\Rightarrow \epsilon_r=3$$

3. (2)



$T\cos\theta=mg$

$T\sin\theta=F_e$

$$\tan\theta=\frac{F_e}{mg}$$

$$\tan\theta=\frac{F_e}{\rho_B Vg} \quad ...(i)$$

$$\tan\theta=\frac{F_e}{\frac{k}{(\rho_B-\rho_L)Vg}} \quad ...(ii)$$

From Eq. (i) & (ii)

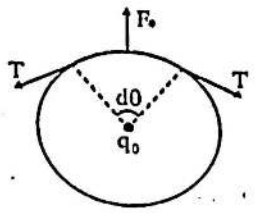
$\rho_B Vg=(\rho_B-\rho_L)kVg$

$1.4=0.7\,k$

the dielectric constant of the liquid is

$k=2$

4. [3]



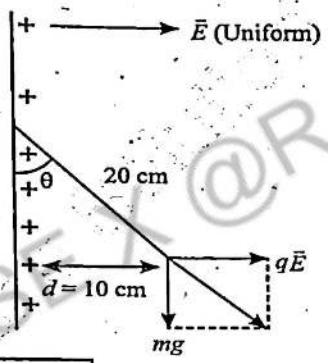
$$\Rightarrow 2T\sin\frac{d\theta}{2}=\frac{kq_0}{R^2}\cdot\lambda R d\theta$$

$$\Rightarrow T=\frac{Kq_0Q}{(R^2)\times 2\pi}$$

$$=\frac{(9\times10^9)(2\pi\times30\times10^{-12})}{(0.30)^2\times2\pi}$$

$$=\frac{9\times10^{-3}\times30}{9\times10^{-2}}=3N$$

5. [3]



$$\boxed{\tan\theta=\frac{qE}{mg}}$$

$$\tan30^\circ=\frac{q\times2\times10^4}{1\times10^{-3}\times10}$$

$$\boxed{\frac{1}{\sqrt{3}}=q\times10^{\square}}$$

$$\boxed{q=\frac{1}{\sqrt{3}}\times10^{-6}C}$$

$x=3$

6. (a) Coulombian force

$$F_e=\frac{kQ_1Q_2}{r^2}$$

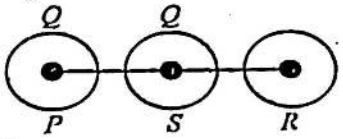
$$=\frac{9\times10^9\times1.6\times10^{-19}\times1.6\times10^{-19}}{r^2}$$

$$F_e=\frac{Gm_1m_2}{r^2}$$

$$=\frac{6.67\times10^{-11}\times9.1\times10^{-31}\times1.6\times10^{-27}}{r^2}$$

$$\frac{F_e}{F_g}\cong0.23\times10^{40}\cong2.3\times10^{39}$$

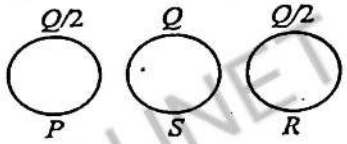
7. (b)



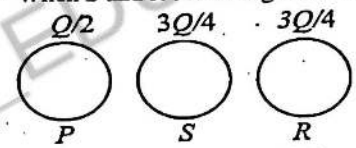
$F_{ps}\propto Q^2$

$F_{PS}=16N$

When P and R are kept in contact then



When S and R are brought in contact then



New force between P and S is :

$$F_{PS}\propto\frac{Q}{2}\times\frac{3Q}{4}$$

$$F_{PS}\propto\frac{3Q^2}{8}=\frac{3}{8}\times16=6N$$

8. (a) Force between the charges in medium,

$$F=\frac{1}{(4\pi\epsilon_0)}\frac{q_1q_2}{kd^2}$$

Force between the charges in air,

$$F_{Air}=\frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{d'^2}$$

Given, $F=F_{Air}$

$$\Rightarrow\frac{q_1q_2}{4\pi\epsilon_0kd^2}=\frac{q_1q_2}{4\pi\epsilon_0d'^2}\quad d'=d\sqrt{k}$$

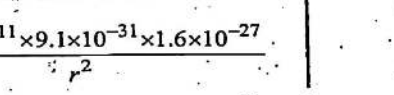
9. (b) Let the charge on first and second part be x & $10-x$ respectively.

$$F=\frac{Kx(10-x)}{r^2}$$

For F to be maximum, $\frac{dF}{dx}=0$

$$=\frac{K}{r^2}(10-2x)=0\quad x=\frac{10}{2}=5\mu C$$

10. [5440]



@FAKE_CBSE_X @RAJ_EDUNET

Force on B due to A

$$F_{BA}=\frac{Kq(2q)}{\left(\frac{3}{4}R\right)^2}=\frac{K32q^2}{9R^2}$$

Force on B due to C

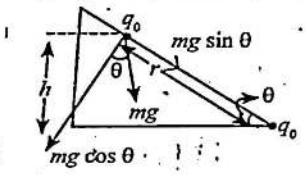
$$F_{BC}=\frac{K(2q)(2q)}{\left(\frac{R}{4}\right)^2}=\frac{64Kq^2}{R^2}$$

Net force on B

$$F_B=F_{BC}-F_{BA}=\frac{544Kq^2}{9R^2}$$

$$=\frac{544\times9\times10^9\times\left(2\times10^{-6}\right)^2}{9\times\left(2\times10^{-2}\right)^2}=5440N$$

11. [300] For equilibrium along the plane



$$mg\sin\theta=K\times\frac{q_0^2}{\left(h\,\mathrm{cosec}\theta^\circ\right)^2}$$

Put θ 30°

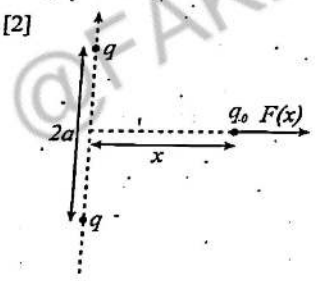
$$\therefore h^2=\frac{1}{K}\times\frac{q_0^2}{mg\,\mathrm{cosec}30^\circ}$$

$$=9\times10^9\times\frac{\left(2\times10^{-6}\right)^2}{0.02\times10\times2}$$

$$\therefore K=\frac{1}{4\pi E_0}=9\times10^9\,N.m^2/C^2$$

$$\therefore h=3\times10^4\times\frac{2\times10^{-6}}{0.2}=0.3\,\mathrm{m}=300\,\mathrm{mm}$$

12. [2]



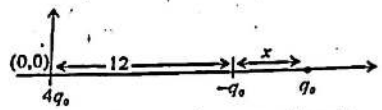
Force acting on the charge q_0,

$$F=\frac{2Kqq_0x}{\left(x^2+a^2\right)^{3/2}}$$

For F to be maximum

$$\frac{dF}{dx}=0\Rightarrow x=\frac{a}{\sqrt{2}}$$

13. [24]



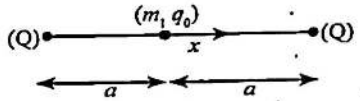
As the net force on the proton is zero

$$\Rightarrow\frac{q_0}{x^2}=\frac{4q_0}{(x+12)^2}\Rightarrow x=12$$

$\Rightarrow$ Distance of the proton from origin = $x+12=24\ cm$.

14. (a) Resultant force on charge q_0

$$F_R=\left\{\frac{kQq_0}{(a-x)^2}-\frac{kQq_0}{(a+x)^2}\right\}$$



$$=-kQq_0\left\{\frac{a^2+x^2+2ax-a^2-x^2+2ax}{\left(a^2-x^2\right)^2}\right\}$$

$$F_R=-\frac{kQq_0(4ax)}{(a^2-x^2)^2}$$

From Newtons second law, $a=\frac{F}{m}$

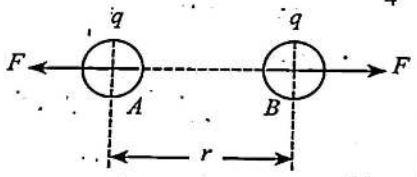
$$\therefore a=-\frac{kQq_0\cdot4a}{a^4m}x=-\left(\frac{4kQq_0}{a^3\omega^2}\right)x$$

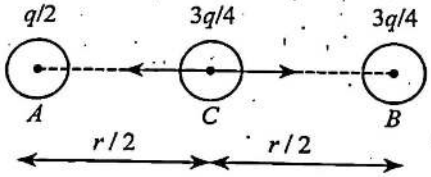
$$T=2\pi\sqrt{\frac{a^3m}{4kQq_0}}=\sqrt{\frac{4\pi^2a^3m\times4\pi\varepsilon_0}{4Qq_0}}$$

$$=\sqrt{\frac{4\pi^3\varepsilon_0ma^3}{Qq_0}}$$

15. (b) For sphere 'C' after contacting with 'A'. $q_A=q_C=\frac{q}{2}$.

After contacting with 'B'. $q_B=q_C=\frac{3q}{4}$





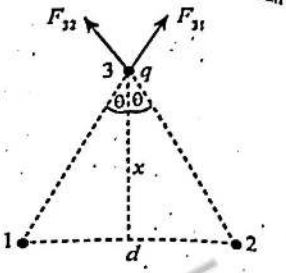
Initially, $F=\frac{kq^2}{r^2}$

$$F_1=\frac{9kq^2}{4r^2}=\frac{9}{4}F$$

$$F_2=\frac{3}{2}\frac{kq^2}{r^2}=\frac{3}{2}F$$

$$\therefore F_{Net}=\frac{9}{4}F-\frac{3}{2}F=\frac{3}{4}F$$

16. (d) According to diagram, we can write



$$F_{31}=F_{32}=\frac{KqQ}{x^2+\left(\frac{d}{2}\right)^2}$$

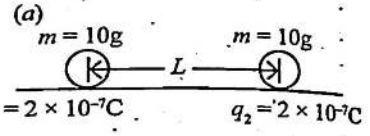
$$\Rightarrow F=2F_{31}\cos\theta=\frac{2KqQx}{\left[x^2+\left(\frac{d}{2}\right)^2\right]^{\frac{3}{2}}}$$

F is net force on q

$\because$ For maxima of force, $\frac{dF}{dx}=0$

On solving, we get $x=\frac{d}{2\sqrt{2}}$

17. (a)



$f_2=\mu N=\mu mg$

According to the question, Coulumb force an each charge = Frictional force

$$\Rightarrow \mu mg=\frac{kq_1q_2}{L^2}$$

$$\Rightarrow 0.25\times0.01\times10$$

$$=\frac{9\times10^9\times2\times10^{-7}\times2\times10^{-7}}{L^2}$$

$$\Rightarrow L=12\ \mathrm{cm}$$

18. (b)

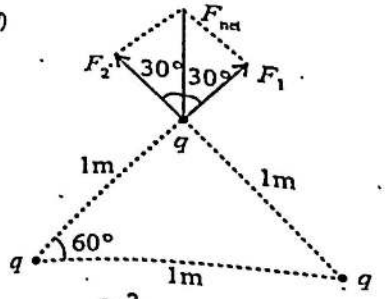
$$F=\frac{kq(4-q)}{d^2}$$

@FAKE_CBSE_X@RAJ_EDUNET

$$\frac{dF}{dq}=0\Rightarrow\frac{k}{d^2}(4-2q)=0$$

$q=2$

19. (*d*)

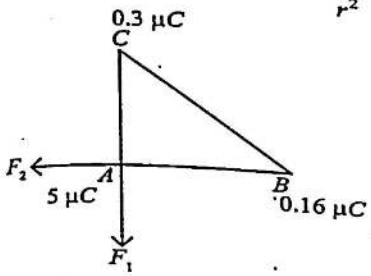


$$F_1=F_2=\frac{kq^2}{1^2}$$

$$F_{net}=2F_1\cos30°$$

$$\therefore\frac{F_{net}}{F_1}=2\cos30°=2\times\frac{\sqrt{3}}{2}=\sqrt{3}:1$$

20. [17] Electrostatic force, $F=\frac{KQ_1Q_2}{r^2}$

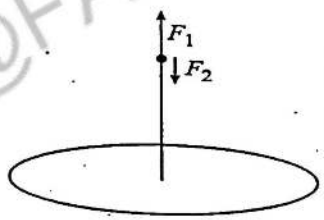


$$F_1=\frac{9\times10^9\times5\times10^{-6}\times0.3\times10^{-6}}{9\times10^{-4}}=15\text{N}$$

$$F_2=\frac{9\times10^9\times5\times10^{-6}\times0.16\times10^{-6}}{9\times10^{-4}}=8\text{N}$$

$$\therefore F_{net}=\sqrt{(15)^2+(8)^2}=17\text{N}$$

21. (*a,c,d*)



$$\vec{F}_1=\frac{q\sigma}{2\epsilon_0}\left(1-\frac{z}{\sqrt{R^2+Z^2}}\right)\hat{k}$$

$$\vec{F}_2=-c\hat{k}$$

$$\beta=\frac{1}{4}$$

$$\therefore\frac{1}{4}=\frac{2c\varepsilon_0}{q\sigma}(\text{Given})\Rightarrow\frac{q\sigma}{2\varepsilon_0}=4c\quad\ldots(i)$$

For equilibrium at $z=Z_0$

$$F_1=F_2\Rightarrow\frac{q\sigma}{2\varepsilon_0}\left(1-\frac{Z}{\sqrt{R^2+Z^2}}\right)=c$$

From equation (*i*)

$$\Rightarrow\left(1-\frac{Z}{\sqrt{R^2+Z^2}}\right)=\frac{1}{4}$$

$$\Rightarrow\frac{Z}{\sqrt{R^2+Z^2}}=\frac{3}{4}$$

$$\Rightarrow Z=\sqrt{\frac{9}{7}}R=1.13R$$

$Z>1.13\,R;F_2>F_1$ Particle reaches origin

$Z<1.13\,R;F_1>F_2$ Particle reaches back to $z=Z_0$

22. (*b*) Distance between the charges $r=\ell\sin\theta+\ell\sin\theta$

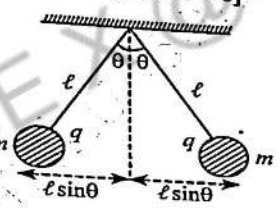
Applying Newton's second law,

$$T\sin\theta=\frac{1}{4\pi\varepsilon_0}\frac{q^2}{(2\ell\sin\theta)^2}\quad\ldots(i)$$

$$T\cos\theta=mg\quad\ldots(ii)$$

$$\therefore\tan\theta=\frac{q^2}{4\pi\varepsilon_0 mg4\ell^2\theta^2}$$

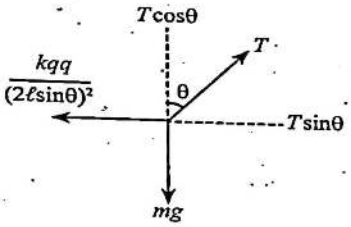
[For small angle, $\tan\theta\approx\theta$]



So, $\theta^3=\frac{q^2}{16\pi\varepsilon_0 mg\ell^2}$

$$\theta=\left(\frac{q^2}{16\pi\varepsilon_0 mg\ell^2}\right)^{1/3}$$

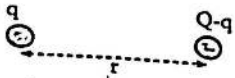
Also separation $=2\ell\sin\theta\cong2\ell\theta$



$$=2\ell\left(\frac{q^2}{16\pi\varepsilon_0 mg\ell^2}\right)^{1/3}=\left(\frac{8q^2\ell^3}{16\pi\varepsilon_0 mg\ell^2}\right)^{1/3}$$

$$=\left(\frac{q^2\ell}{2\pi\varepsilon_0 mg}\right)^{1/3}$$

23. (*c*)



The electrostatic repulsion force between q and $Q-q$.

$$F=\frac{q(Q-q)}{4\pi\varepsilon_0 r^2}\Rightarrow\frac{dF}{dq}=\frac{1}{4\pi\varepsilon_0 r^2}(Q-2q)$$

For maxima of force, $\frac{dF}{dq}=0$

On differentiating F w.r.t q

$$\frac{dF}{dq}=\frac{1}{4\pi\varepsilon_0 r^2}(Q-2q)=0\Rightarrow q=\frac{Q}{2}$$

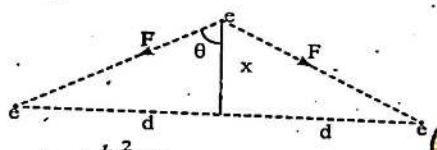
24. (*d*) From observation, we can say that net force on the charge particle at point P is zero.

So, $\frac{k(5\mu C)q}{x^2}=\frac{k(20\mu C)q}{(5+x)^2}$

$$\Rightarrow\frac{1}{x^2}=\frac{4}{(5+x)^2}\Rightarrow\left(\frac{5+x}{x}\right)^2=2^2$$

$$\Rightarrow\frac{5+x}{x}=2\Rightarrow x=5\text{ cm}$$

25. (*c*)

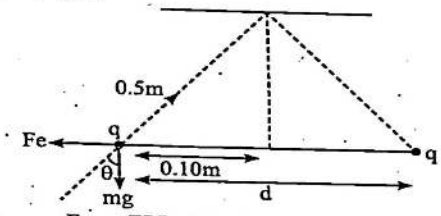


os $\theta=2\times\frac{ke^2\times x}{\left(x^2+d^2\right)^{3/2}}$

$\therefore x<<d$

$\therefore F_{net}=\frac{2ke^2}{d^3}x.$

26. [20]



From *FBD*, $T\sin\theta=kq_2/d_2$ and $T\cos\theta=mg$ Dividing them,

$Mg\tan\theta=kq^2/d^2$

$q=\sqrt{(mg\tan\theta)/25k}$

$=\sqrt{(10\times10^{-6}\times10\times1/\sqrt{24(25)9\times10^9})}$

@FAKE_CBSE_X@RAJ_EDUNET

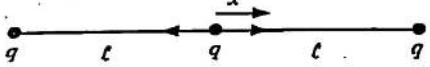
$= \sqrt{(10^{-4} \times 4 / \sqrt{24 \times 25 \times 4 \times 9 \times 10^9})}$

$= \sqrt{(10^{-4} / \sqrt{24 \times 10^{11}})}$

Thus $(a/21) \times 10^{-4} = \frac{2}{3}\sqrt{(10^{-15} / \sqrt{24})}$

$a = 20$

27. [6000] Net force on free charge particle,



$$F_{net} = \frac{kq^2}{(\ell+x)^2} - \frac{kq^2}{(\ell-x)^2}$$

$$= kq^2\left[\frac{(\ell-x)^2-(\ell+x)^2}{(\ell^2-x^2)^2}\right] = \frac{kq^2}{\ell^4}(-4\ell x)$$

$[x << \lambda]$

From Newton's II-law, $F_{net} = ma$

$$\therefore ma = \frac{kq^2}{\ell^4}(-4\ell x) = -\frac{4kq^2}{\ell^3}x$$

$a = -\frac{4kq^2}{m\ell^3}x$ Comparing with $a = -\omega^2 x$.

$$\omega = \sqrt{\frac{4kq^2}{m\ell^3}} = \sqrt{\frac{4\times9\times10^9\times10}{1\times10^{-6}\times1}}$$

6×10^8 rad/s $= 6000 \times 10^5$ rad/s

28. [36] $q = \frac{(2.1-0.1)}{2}nC = 1nC$

(final charge on both sphere)

$$F = \frac{9\times10^9\times10^{-18}}{(0.5)^2} = 36\times10^{-9}\left(F = k\frac{q_1 \times q_2}{r^2}\right)$$

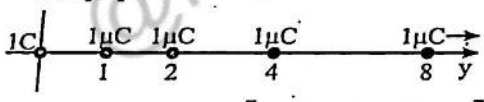
29. (a) $neE = \frac{4}{3}\pi r^3 \cdot \rho g$ [$\because q = ne$]

$$\Rightarrow n = \frac{4\pi r^3 \rho g}{3eE}$$

$$= \frac{4\times3.14\times\left(2\times10^{-3}\right)^3\times3\times10^3\times9.81}{3\times1.6\times10^{-19}\times3.55\times10^5}$$

$= 1.73 \times 10^{10}$

30. [12]



$$F = k(1C)(1\mu C)\left[1+\frac{1}{2^2}+\frac{1}{4^2}+\frac{1}{8^2}+\ldots\right]$$

$$= 9\times10^3\left[\frac{1}{1-\frac{1}{4}}\right] = 12\times10^3\,N$$

31. (c) For spherical shell

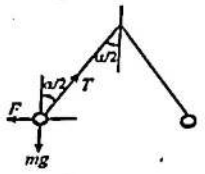
$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ $(r > R)$

$= 0$ $(r < R)$

Force on charge in electric field

$F = qE$

32. (a,c) From coulomb law the force due to one sphere to another remain the same. In equilibrium



$T\cos\frac{\alpha}{2} = mg$ and $T\sin\frac{\alpha}{2} = F$

After immersed is dielectric liquid.

As given no change in angle α..

So $T\cos\frac{\alpha}{2} = mg - V\rho g$

when $\rho = 800$ Kg/m³

and $T\sin\frac{\alpha}{2} = \frac{F}{\varepsilon_r}$

$$\therefore \frac{mg}{F} = \frac{mg - V\rho g}{\frac{F}{\varepsilon_r}}$$

$\frac{1}{\varepsilon_r} = 1 - \frac{\rho}{d}$ d = density of sphere

$\frac{1}{21} = 1 - \frac{800}{d} \Rightarrow d = 840$

33. (c) $E \cdot 4\pi r^2 = \frac{\int_0^r (kr)\cdot 4\pi r^2 dr}{\varepsilon_0}$

$\Rightarrow E = \frac{kr^2}{4\varepsilon_0}$ ...(i)

Now, $2Q = \int_0^R kr \cdot 4\pi r^2 dr$

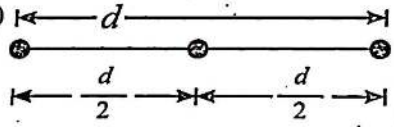
$\Rightarrow K = \frac{2Q}{\pi R^4}$ ...(ii)

$E = \frac{Qr^2}{2\pi\varepsilon_o R^4}$ [From (i) and (ii)]

$\because F_{net} = 0 \Rightarrow \frac{Q2}{4\pi\varepsilon_o(2a)^2} = EQ$

$a = R \cdot 8^{-1/4}$.

34. (a)



$\vec{F}_1 + \vec{F}_2 = 0$

$\Rightarrow \vec{F}_1 = -\vec{F}_2$ ...(i)

$\frac{KQq}{\left(\frac{d}{2}\right)^2} = \frac{-KQQ}{d^2} \Rightarrow q = \frac{-Q}{4}$

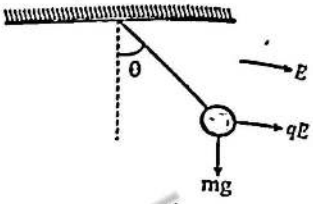
35. (b)

$$Q = \int \rho 4\pi r^2 dr = \int_0^R \left(\frac{A}{r^2}e^{-\frac{2r}{a}}\right)(4\pi r^2)dr$$

$$= 4\pi A\frac{a}{2}\left(1 - e^{\frac{-2R}{a}}\right)$$

$$R = \frac{a}{2}\log\left(\frac{1}{1-\frac{Q}{2\pi aA}}\right)$$

36. (c)



$$\tan\theta = \frac{qE}{mg} = \frac{5\times10^{-6}\times2000}{2\times10^{-3}\times10}$$

$\tan\theta = \frac{1}{2} \Rightarrow \theta = \tan^{-1}(0.5)$

37. (b,d) General equation of SHM

$x = A\sin(\omega' t \pm \phi)$

We know, $\omega = \frac{2\pi}{T}$

Given, $T = \frac{\pi}{\omega}$

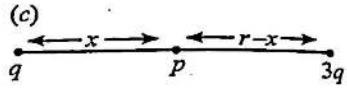
$\therefore \omega' = \frac{2\pi}{\frac{\pi}{\omega}} = 2\omega$

$\therefore$ Equation becomes,

$x = a\sin(2\omega t \pm \phi)$

Here coefficient of t is 2ω.

38. (c)



$\left(\vec{E}_{net}\right)_P = 0$

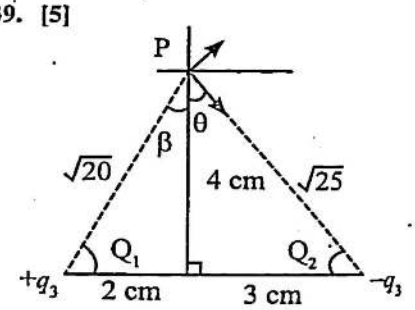
$\frac{kq}{x^2} = \frac{k\cdot3q}{(r-x)^2}$

$(r-x)^2 = 3x^2$

$r - x = \sqrt{3}x$

$x = \frac{r}{\sqrt{3}+1}$

39. [5]



@FREE CBSE X @RAJEDUNET

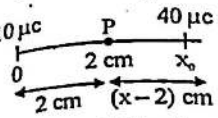
since net electric field at point P is zero so,

$$\frac{Kq_2}{20}\cos\beta = \frac{Kq_3}{25}\cos\theta$$

$$\frac{Kq_2}{20}\cdot\frac{4}{\sqrt{20}} = \frac{Kq_3}{25}\cdot\frac{4}{\sqrt{25}}$$

$$\frac{q_2}{q_3} = \frac{20}{25}\sqrt{\frac{20}{25}} = \frac{8}{5\sqrt{x}} \Rightarrow 7 \Rightarrow x = 5$$

40. (a)



For the electric field to be zero at $x = 2$ cm from the 10μc charge.

$$E_P = \frac{K\times 10}{2^2} - \frac{K\times 40}{(x-2)^2} = 0$$

$$\frac{1}{2} = \frac{2}{x-2} \Rightarrow x = 6 \text{ cm}$$

41. (b) Electric field inside material of conductor is zero.

42. [6] $E_P = \dfrac{\lambda}{2\pi\varepsilon_0 r_P} - \dfrac{\sigma}{2\varepsilon_0}$

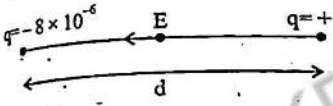
$$= \frac{1}{2\varepsilon_0}\frac{\lambda}{3} - \sigma \qquad \left[\text{For, } r_P = \frac{3}{\pi}\right]$$

$$E_Q = \frac{\lambda}{2\pi\varepsilon_0 r_Q} - \frac{\sigma}{2\varepsilon_0}$$

$$= \frac{1}{2\varepsilon_0}\left|\frac{\lambda}{4} - \sigma\right| \qquad \left[\text{For, } r_Q = \frac{4}{\pi}\right]$$

$$\frac{E_P}{E_Q} = \frac{4}{3}\left(\frac{\lambda-3\sigma}{\lambda-4\sigma}\right) = \frac{4}{3}\left(\frac{2\sigma-3\sigma}{2\sigma-4\sigma}\right) = \frac{4}{6}$$

43. (b)

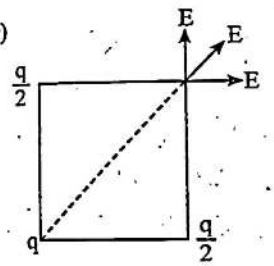


$$E = \frac{k\cdot q}{\left(\frac{d}{2}\right)^2}\times 2 \Rightarrow d^2 = \frac{8kq}{E}$$

$$d^2 = \frac{8\times 9\times 10^9 \times 8\times 10^{-6}}{6.4\times 10^4} \Rightarrow d = 3 \text{ m}$$

44. (c) $E_1 = E_2 = \dfrac{\sigma}{2\varepsilon_0}$

45. (a)



$$E = \frac{1}{4\pi\epsilon_0}\cdot\frac{(q/4)}{a^2}$$

$$E_{net} = \sqrt{2}E + E$$

$$= \frac{q}{4\pi\epsilon_0 a^2}\left(\frac{\sqrt{2}+1}{2}\right)$$

46. [24] Using work . energy theorem, = gain in spring energy

$$\Rightarrow \frac{3E}{4} = \frac{1}{2}k\left(\frac{25}{100}\right)^2$$

$$\Rightarrow \frac{3E}{4} = \frac{k}{32} \Rightarrow k = 24E$$

$\therefore n = 24.$

47. (a) $neE = \dfrac{4}{3}\pi r^3\cdot\rho g$ [$\because q = ne$]

$$\Rightarrow n = \frac{4\pi r^3\rho g}{3eE}$$

$$= \frac{4\times 3.14\times(2\times 10^{-3})^3\times 3\times 10^3\times 9.81}{3\times 1.6\times 10^{-19}\times 3.55\times 10^5}$$

$$= 1.73\times 10^{10}$$

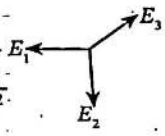
48. (b) $dA = 2\pi r\,dr$

$dq = \sigma\times 2\pi r\,dr$

$$\Rightarrow E = \int_0^R \frac{kdqZ}{\left(Z^2+r^2\right)^{3/2}}$$

$$\Rightarrow E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{Z}{\sqrt{R^2+Z^2}}\right]$$

49. (a) $E_1 = \dfrac{kq}{\ell^2} = E_2$



$$E_3 = \frac{kq}{(\sqrt{2}\ell)^2} = \frac{kq}{2\ell^2}$$

$$E = \frac{kq}{2\ell^2}\left(2\sqrt{2} - 1\right)$$

50. (a) The linear charge density of wire,

$$\lambda = \frac{-Q}{R\times 2\pi/3}$$

The electric field at the centre of curvature,

$$\vec{E} = \frac{2k\lambda}{R}\sin\left(\frac{\theta}{2}\right)\left(-\hat{i}\right)$$

$$\Rightarrow \vec{E} = \frac{2k}{R}\times\frac{-3Q}{2\pi R}\sin 60^\circ\left(-\hat{i}\right)$$

$$\Rightarrow \vec{E} = \frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}\left(-\hat{i}\right)$$

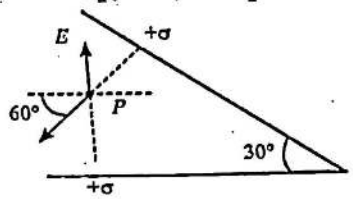
51. (a) Electric field due to each sheet

$$\vec{E} = \frac{\sigma}{2\varepsilon_o}$$

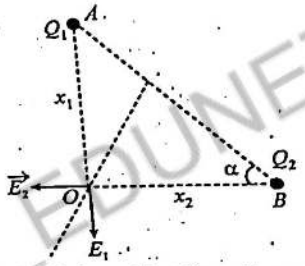
So, net electric field between plates

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\cos 60^\circ(-\hat{x}) + \left[\frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0}\sin 60^\circ\right](\hat{y})$$

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\left[\left(1-\frac{\sqrt{3}}{2}\right)\hat{y} - \frac{1}{2}\hat{x}\right]$$



52. (c)

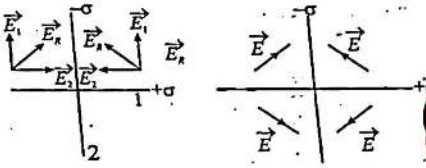


Net field along AB at O must be zero

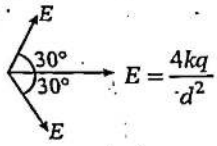
$E_2\cos\alpha = E_1\sin\alpha$

$$\frac{kQ_2}{x_2^2}\cdot\frac{x_2}{AB} = \frac{kQ_1}{x_1^2}\cdot\frac{x_1}{AB} \Rightarrow \frac{Q_1}{Q_2} = \frac{x_1}{x_2}$$

53. (d)



54. (a)



$$E_{net} = \frac{4kq}{d^2}\times 2\cos 30^\circ = \frac{q\sqrt{3}}{\pi\varepsilon_0 d^2},$$

55. (a) For a solid sphere

$E = \dfrac{\rho r}{3\varepsilon_0}$ for $(r < R)$; $E_A = \dfrac{-\rho R}{2(3\varepsilon_0)}$; $|E_A| = \dfrac{\rho R}{6\varepsilon_0}$

Electric field at point $B = E_B = E_{1A} + E_{2A}$

E_{1A} = Electric field due to solid sphere of radius R at point $B = \dfrac{\rho R}{3\varepsilon_0}$

@FAKE_CBSE_X @RAJ EDUNET

E_{2A} = Electric field due to solid sphere of radius $R/2$ (which having charge density–ρ)

$$E_{2A}=-\frac{KQ'\times 4}{9R^2}=-\frac{\rho R}{54\varepsilon_0}$$

$$\left(Q'=\frac{\rho 4}{3}\pi\left(\frac{r}{2}\right)^3\right)$$

$$E_B=E_{1A}+E_{2A}=\frac{\rho R}{3\varepsilon_0}-\frac{\rho R}{54\varepsilon_0}=\frac{17\rho R}{54\varepsilon_0}$$

$$\left|\frac{E_A}{E_B}\right|=\frac{9}{17}=\frac{2\times 9}{2\times 17}=\frac{18}{34}$$

56. (a) $\vec{E}=\frac{kq_1}{r_1^3}\vec{r}_1+\frac{kq_2}{r_2^3}\vec{r}_2$

$$=k\times 10^{-6}\left[\frac{\sqrt{10}}{10\sqrt{10}}\left(-\hat{i}+3\hat{j}\right)+\frac{(-25)}{125}\left(-4\hat{i}+3\hat{j}\right)\right]$$

$$=(9\times 10^3)\left[\frac{1}{10}\left(-\hat{i}+3\hat{j}\right)-\frac{1}{5}\left(-4\hat{i}+3\hat{j}\right)\right]$$

$$=(9\times 10^3)\left[\left(-\frac{1}{10}+\frac{4}{5}\right)\hat{i}+\left(\frac{3}{10}-\frac{3}{5}\right)\hat{i}\right]$$

$$=9000\left(\frac{7}{10}\hat{i}-\frac{3}{10}\hat{j}\right)$$

$$=\left(63\hat{i}-27\hat{j}\right)(100)$$

57. (b) Electric field

$$E=\frac{kQh}{(h^2+R^2)^{3/2}}$$

For maxima $\frac{dE}{dh^2}=0$

After solving we get, $\left(h=\pm\frac{R}{\sqrt{2}}\right)$

58. (d) Electric field at p

$$=2E_1\cos\theta_1-2E_2\cos\theta_2$$

$$=\frac{2kq}{\left(d^2+D^2\right)}\times\frac{D}{\left(d^2+D^2\right)^{1/2}}$$

$$-\frac{2kq}{\left[(2d)^2+D^2\right]}\times\frac{D}{\left[(2d)^2+D^2\right]^{1/2}}$$

$$=2kqD\left[\left(d^2+D^2\right)^{-3/2}-\left(4d^2+D^2\right)^{-3/2}\right]$$

$$=\frac{2kqD}{D^3}\left[\left(1+\frac{d^2}{D^2}\right)^{-3/2}-\left(1+\frac{4d^2}{D^2}\right)^{-3/2}\right]$$

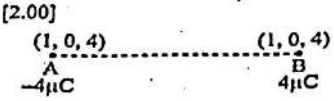
Applying binomial approximation $\because d<<D$

$$=\frac{2kqD}{D^3}\left[1-\frac{3}{2}\frac{d^2}{D^2}-\left(1-\frac{3\times 4d^2}{2D^2}\right)\right]$$

$$=\frac{2kqD}{D^3}\left[\frac{12}{2}\frac{d^2}{D^2}-\frac{3}{2}\frac{d^2}{D^2}\right]$$

$$=\frac{9kqd^2}{D^4}$$

59. [2.00]



As, $\vec{p}=q\vec{\ell}$ and $\vec{\tau}=\vec{p}\times\vec{E}$

$$\vec{E}=0.2\frac{V}{cm}=20\frac{V}{m}$$

$$\vec{p}=4\times\left(\hat{i}-\hat{j}+\hat{k}\right)$$

$$=\left(4\hat{i}-4\hat{j}+4\hat{k}\right)\mu C-m$$

$$\vec{\tau}=\left(4\hat{i}-4\hat{j}+4\hat{k}\right)\times\left(20\hat{i}\right)\times 10^{-6}Nm$$

$$=\left(8\hat{k}+8\hat{j}\right)\times 10^{-5}=8\sqrt{2}\times 10^{-5}$$

$\alpha=2$

60. [16] Electric field at point P

$$E_P=\frac{2KP}{r^3}=E$$

Electric field at point R,

$$E_R=\frac{KP}{(2r)^3}=\frac{E}{16}$$

$x=16$

61. (c) Electric field due to a dipole at point on its equatorial plane

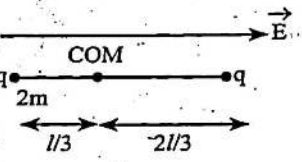
$$=\frac{1}{4\pi\epsilon_0}\frac{2p}{r^3}\Rightarrow E\propto\frac{1}{r^3}$$

62. (b) $|\vec{\tau}|=PE\sin\theta=(q.d)E\sin\theta$

$=0.01\times 0.4\times 10^{-3}\times 10\times 10^{-5}\times\sin 30°$

$=2\times 10^{-10}$ N.m

63. (*)



If released, it will oscillate about centre of mass(COM).

$\tau=-pE.\sin\theta=-pE.\theta$ {$\because\theta$ is small}

$$\Rightarrow\left[2m\frac{l^2}{9}+m\frac{4l^2}{9}\right]\alpha=-qlE.\theta$$

$$\Rightarrow\frac{2ml^2}{3}\alpha=-qlE\cdot\theta\Rightarrow\alpha=-\frac{3qE}{2ml}\theta$$

∴ Angular frequency

$$\omega=\sqrt{\frac{3qE}{2ml}}\quad\text{(Bonus)}$$

64. (a) Force on charges will be diffrent in nonuniform field.

65. [6] $|\tau|_{max}=PE$

So,

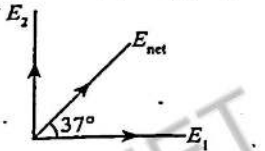
$$\frac{\tau_1}{\tau_2}=\frac{P_1E_1}{P_2E_2}=\frac{\left(1.2\times 10^{-30}\right)\times\left(5\times 10^4\right)}{\left(2.4\times 10^{-30}\right)\times\left(15\times 10^4\right)}=\frac{1}{6}$$

$$\therefore\frac{1}{6}=\frac{1}{x}\Rightarrow x=6$$

66. (d) Electric field at an axial line of a dipole, $E_1=k\frac{2p_1}{r^3}$

Electric field at on equatorial line of a dipole, $E_2=k\frac{p_2}{r^3}$

$$\tan 37°=\frac{E_1}{E_1}=\frac{p_2}{2p_1}=\frac{3}{4}$$



$$\frac{p_1}{p_2}=\frac{2}{3}$$

67. (d) $\left|\vec{F}\right|=q\left(\left|\vec{E}_1\right|-\left|\vec{E}_2\right|\right)=2k\lambda q\left[\frac{1}{r_1}-\frac{1}{r_2}\right]$

$$\left|\vec{F}\right|=2\times 9\times 10^9\times 3\times 10^{-6}\left[\frac{1000}{10}-\frac{1000}{12}\right]q$$

$4=9\times 10^5\,q$

$$q=\frac{4}{9\times 10^5}=4.44\mu C$$

68. (a) Since, $\vec{p}.\vec{r}=0$

$\vec{E}$ must be antiparallel to $\vec{p}$

So, $\vec{E}=-\lambda(-\vec{p})$

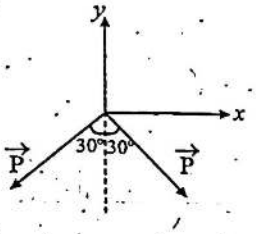
where λ is an arbitary positive constant

Now $\vec{A}=a\hat{i}+b\hat{j}+c\hat{k}$

$\vec{A}\|\vec{E}$

$$\frac{a}{\lambda}=\frac{b}{3\lambda}=\frac{c}{-2\lambda}=k$$

69. (d)



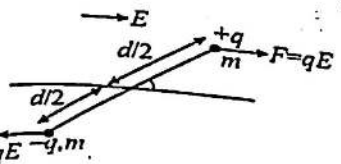
$$\left|\vec{P}\right|=ql$$

$$\vec{P}_{net}=2P\cos 30°\left(-\hat{j}\right)=P\sqrt{3}\left(-\hat{j}\right)$$

$$=\sqrt{3}\,ql\left(-\hat{j}\right)=-\sqrt{3}\,q\ell\,\hat{j}$$

@FIITJEE_CBSE_@RAJ_EDUNET

70. (c)



momentofinertia $(I) = m\left(\frac{d}{2}\right)^2 \times 2 = \frac{md^2}{2}$

Now by $\tau = I\alpha$

$(qE)(d\sin\theta) = \frac{md^2}{2}\cdot\alpha$

$\alpha = \left(\frac{2qE}{md}\right)\sin\theta$

for small θ, $\sin\theta \approx \theta$

$\Rightarrow \alpha = \left(\frac{2qE}{md}\right)\theta \Rightarrow w = \sqrt{\frac{2qE}{md}}$

71. (b) $\frac{2k\lambda q}{r} = m\omega^2 r$

$\omega^2 = \frac{2k\lambda q}{mr^2}$

$\left(\frac{2\pi}{T}\right)^2 = \frac{2k\lambda q}{mr^2}$

$T = 2\pi r\sqrt{\frac{m}{2k\lambda q}}$

72. [8] $u = 1$ m/s; $a = -\frac{\sigma e}{2\varepsilon_0 m}$

$t = 1$ s

$S = -1$ m

Using $S = ut + \frac{1}{2}at^2$

$-1 = 1\times 1 - \frac{1}{2}\times\frac{\sigma e}{2\varepsilon_0 m}\times(1)^2$

$\therefore \sigma = 8\frac{\varepsilon_0 m}{e}\times(1)^2$

$\therefore \alpha = 8$

73. [45] $\because 0.5e = \frac{1}{2}mv_x^2$

$\Rightarrow v_x = \sqrt{\frac{e}{m}}$

Along x axis, $L = v_x t = \sqrt{\frac{e}{m}}t$ ...(i)

Along y axis $v_y = \frac{eE}{m}t$ ...(ii)

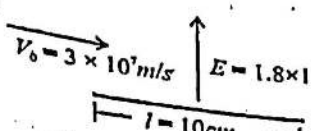
$\frac{v_y}{L} = E\sqrt{\frac{e}{m}} = Ev_x$

$\because \tan\theta = \frac{v_y}{v_x}$

$\Rightarrow \tan\theta = E\times L = 10\times 0.1 = 1$

$\Rightarrow \theta = 45°$

74. [2]



$\because a = \frac{qE}{m} = \left(2\times10^{11}\right)\left(1.8\times10^3\right)$

$= 3.6\times10^{14}\ m/s^2$

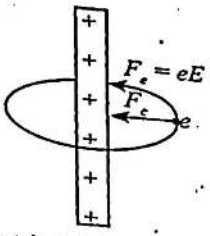
Time to cross plates $= \frac{d}{v}$

$\Rightarrow t = \frac{0.10}{3\times10^7}$

$y = \frac{1}{2}at^2 = \frac{1}{2}\left(3.6\times10^{14}\right)\left(\frac{0.01}{9\times10^{14}}\right)$

$= 0.2\times0.01 \Rightarrow = 2$ mm

75. [8]



Centripetal force is provided by electric field.

$F_e = F_c$

$eE = \frac{mv^2}{r} \Rightarrow e\cdot\frac{2k\lambda}{r} = \frac{mv^2}{r}$

$V = \sqrt{\frac{e\cdot 2k\lambda}{m}}$

$= \sqrt{\frac{1.6\times10^{-19}\times2\times9\times10^9\times2\times10^{-8}}{9\times10^{-31}}}$

$= \sqrt{64\times10^{12}}$

76. (b) $qE = mg$

$\Rightarrow q = \frac{mg}{E} = 2\times10^{-9}$ C.

77. (b) We have, $E = \frac{8m}{e}$ v/m

time to come out, $t = \frac{1}{2}$ sec

$V_y = at = \left(\frac{eE}{m}\right)t = \left(\frac{e}{m}\times\frac{8m}{e}\right)\times\frac{1}{2} = 4$m/s

So, $\tan\theta = \frac{V_y}{V_x} = \frac{4}{2} \Rightarrow \theta = \tan^{-1}2$

78. (a) Electric field at the surface of cylinder $= \frac{\delta R}{2\varepsilon_0}$

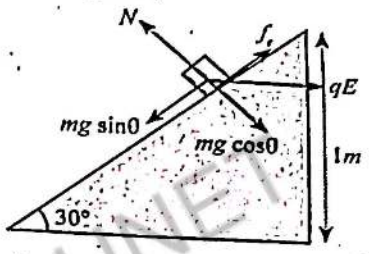
$\therefore qE = \frac{mv^2}{R}$

$\Rightarrow q\times\frac{\rho R}{2\varepsilon_0} = \frac{mv^2}{R} \Rightarrow mv^2 = \frac{\rho qR^2}{2\varepsilon_0}$

$\therefore K\cdot E = \frac{\rho qR^2}{4\varepsilon_0}$

79. (d) $S = \frac{v^2}{2a} = \frac{v^2}{2\left(\frac{qE}{m}\right)}$

80. (a) Using FBD,



$F = mg\sin\theta - qE\cos\theta - \mu N$

Here $N = mg\cos\theta + qE\sin\theta$

$\therefore F = \frac{9.8}{2} - \frac{5\times10^{-3}\times200\times\sqrt{3}}{2}$

$-0.2\left(\frac{5\times10^{-3}\times200}{2} + \frac{1\times9.8\times\sqrt{3}}{2}\right)$

$F = 2.25$ N

$\Rightarrow a = 2.25$ m/s²

$S = ut + \frac{1}{2}at^2$

$\Rightarrow t = \sqrt{\frac{2\ell}{a}} = 1.31$sec

81. [1] Electric force acting on the body, $F = qE$

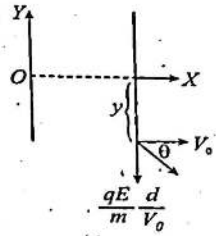
Accleration of body,

$a = \frac{F}{m} = \frac{q}{m}E = \frac{8\times10^{-6}}{10^{-3}}\times100 = 0.80$m/s²

$\therefore$ Time period of Motion,

$T = 2\sqrt{\frac{2\ell}{a}} = 2\sqrt{\frac{2\times0.1}{0.8}} = 1$s

82. (c)



$y = \frac{1}{2}\left(\frac{qE}{m}\right)\left(\frac{d}{V_0}\right)^2$

@FAKE_CBSE_X @RAJ_EDUNET

$$y=-\frac{qEd}{mV_0^2}x+C$$

At $x=d$,

$$y=-\frac{qEd^2}{2mV_0^2}\Rightarrow C=\frac{qEd^2}{2mV_0^2}$$

$$y=-\frac{qEd}{mV_0^2}x+\frac{qEd^2}{2mV_0^2}$$

$$y=\frac{qEd}{mV_0^2}\left(\frac{d}{2}-x\right)$$

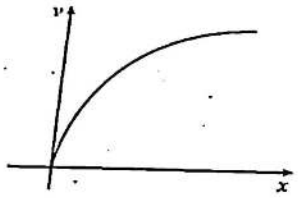
83. (a) $E=E_0(1-ax^2)$

$$\frac{vdv}{dx}=\frac{qE_0}{m}(1-ax^2)$$

$$\Rightarrow \frac{v^2}{2}=\frac{qE_0}{m}\left[x-\frac{ax^3}{3}\right]=0$$

$$\Rightarrow x=\sqrt{\frac{3}{a}}$$

84. (d) $v^2=\frac{2qE}{m}x$



85. (b) $\vec{F}=qE\hat{i}+mg\hat{j}$

Since initial velocity is zero. It will move in straight line.

86. (b,c)

$$a_y=-400\sqrt{3}\times10^{10}\quad [qE_y=ma_y]$$

$$R=5=\frac{40\times10^{12}\sin 2\theta}{400\sqrt{3}\times10^{10}}$$

$$\left[R(\text{range})=\frac{u^2\sin 2\theta}{a_y}\right]$$

$$\sin 2\theta=\frac{\sqrt{3}}{2}$$

$2\theta=60°, 120\Rightarrow\theta=30°, 60°$

Time of flight,

$$T_1=\frac{2\times2\sqrt{10}\times10^6\times\frac{1}{2}}{400\sqrt{3}\times10^{10}}=\sqrt{\frac{5}{6}}\mu s$$

(for $\theta=30°$)

Time of flight,

$$T_2=\frac{2\times2\sqrt{10}\times10^6\times\frac{\sqrt{3}}{2}}{400\sqrt{3}\times10^{10}}=\sqrt{\frac{5}{3}}\mu s$$

(for $\theta=60°$)

87. [6] $E=\frac{V}{d}=\frac{200}{0.01}=2\times10^4$ V/m

When terminal velocity is achieved

$qE=mg\Rightarrow n\times1.6\times10^{-19}\times2\times10^4$

$=\frac{4\pi}{3}\left(8\times10^{-7}\right)^3\times900\times10\Rightarrow n\approx6$

88. (a) $\boxed{\phi_{\text{bigger cube}}=\frac{5Q}{\epsilon_0}}$

$\boxed{\phi_{\text{smaller cube}}=\frac{2Q}{\epsilon_0}}$

$\Rightarrow\boxed{\frac{\phi_{\text{smaller cube}}}{\phi_{\text{bigger cube}}}=\frac{2}{5}}$

89. (c) $\vec{E}=6\hat{i}+5\hat{j}+3\hat{k}$

$\vec{A}=30\hat{i}$

Electric flux through a surface area lying in YZ-plane

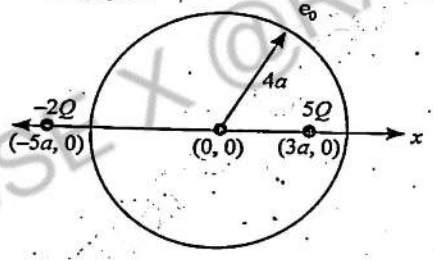
$\phi=\vec{E}.\vec{A}$

$\phi=\left(6\hat{i}+5\hat{j}+2\hat{k}\right).\left(30\hat{i}\right)$

$\phi=6\times30=180$

90. (b)

flux throuhg sphere $=\frac{\text{total charge enclosed in sphere}}{\epsilon_0}$



5Q charge is inside the spherical region flux through sphere $=\frac{5Q}{\epsilon_0}$

91. (2) Electric field E at a distance r due to infinite long wire is $F=\frac{2k\lambda e}{r}$

$F=e\left(\frac{2k\lambda}{r}\right)$ [As, F = eE]

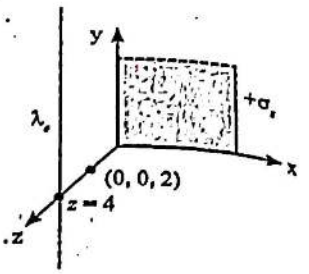
$F=\frac{2k\lambda e}{r}$

Now, $F=\frac{mv^2}{r}=\frac{2k\lambda e}{r}$

$\Rightarrow v=\sqrt{\frac{2k\lambda e}{m}}$

$KE=\frac{1}{2}mv^2=\frac{1}{2}m\left(\frac{2k\lambda e}{m}\right)=k\lambda e$

92. (16)



$$\frac{E_s}{E_l}=\frac{\sigma}{2\epsilon_0}\times\frac{2\pi\epsilon_0 r}{\lambda}=\frac{\pi\times\sigma r}{\lambda}$$

$$=\frac{\pi\times2\lambda\times2}{\lambda}=\frac{4\pi}{1}$$

$\therefore n=16$

93. (b) From Gauss's Law

Cover the charge completely by another identical cube. flux through each $=\phi$

$2\phi=\frac{q}{\epsilon_0}$

$\phi=\frac{q}{2\epsilon_0}$

94. (2) From Gauss's law

$$E'A=\frac{\sigma\times A}{\varepsilon_0}\Rightarrow E=\frac{r}{\varepsilon_0}$$

95. [12] Electric flux for the surface,

$\phi=\vec{E}\cdot\vec{A}$

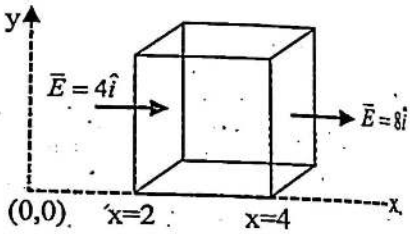
$$=\left(\frac{2\hat{i}+6\hat{j}+8\hat{k}}{\sqrt{6}}\right)\cdot4\left(\frac{2\hat{i}+\hat{j}+\hat{k}}{\sqrt{6}}\right)$$

$$=\frac{4}{6}\times(4+6+8)=12\text{Vm}$$

96. (b) From gauss law electricflux through a surface,

$$\phi=\frac{q_{in}}{\varepsilon_0}=\frac{q+(-2q)+5q}{\varepsilon_0}=\frac{4q}{\varepsilon_0}$$

97. (16)



$\vec{E}=2x\hat{i}$

$\phi=\vec{E}\cdot\vec{A}$

$\phi_{in}=-4\times4=-16\text{Nm}^2/\text{c}$

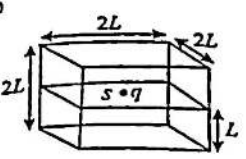
$\phi_{out}=8\times4=32\text{ Nm}^2/\text{c}$

The net electric flux through the cube,

$\phi_{net}=\phi_{in}+\phi_{out}=-16+32=16\text{ Nm}^2/\text{c}$

@FAKE_CBSE_X @RAJ_EDUNET

98. (d) Total electric flux through the cube $\phi = q/\varepsilon_0$



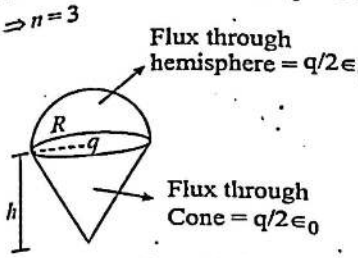
Flux passing through the face opposite to surface $S = \frac{q}{6\varepsilon_0}$

99. [640] Electric Flux $= \vec{E} \cdot \vec{A}$
$= 4000(0\cdot2)^2 \times (0\cdot2)^2$
$= 4000 \times 16 \times 10^{-4}$ Vm $= 640$ V cm

100. (*) $\because$ Flux through curve surface of hemisphere $\phi = \frac{q}{2\varepsilon_0}$

Note: Flux through flat surface should be zero, but option is not given. Hence it is bonus.

101. [3] Flux through cone $= \frac{q}{2\epsilon_0} = \frac{nq}{6\epsilon_0}$
$\Rightarrow n = 3$

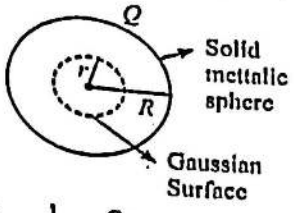


102. (c) Total flux through the cube $= (q/\epsilon_0) \times 1/8 = q/8\epsilon_0$
Total flux through one "outer" face of the cube $= (q/8\epsilon_0) \times 1/3 = q/24\epsilon_0$
[Because there is flux only through 3 faces]
Hence, total flux through shaded area
$\phi_T = (q/25\varepsilon_0 + q/24\varepsilon_0) \times ½$ [half of each face is shaded]
$\phi_T = q/24\varepsilon_0$

103. (a) We know that a dipole is a pair of equal and opposite charges separated by a small distance.
$\because$ The net charge on the electric dipole,
$q_{net} = +q - q = 0$
Therefore, according to Gauss's law,
Electric flux, $\oint \vec{E} \cdot \vec{ds} = \frac{q_{net}}{\varepsilon_0} = \frac{0}{\varepsilon_0} = 0$

Where, $\vec{E}$ is the electric field, $\vec{ds}$ is the surface area a small section, and ε_0 is permittivity in free space.
And for a small section $\vec{ds}$ only, $\vec{E} \cdot \vec{ds} \neq 0$
$\because$ The flux of the electric field throughout the hollow sphere is zero and the electric field is non-zero.

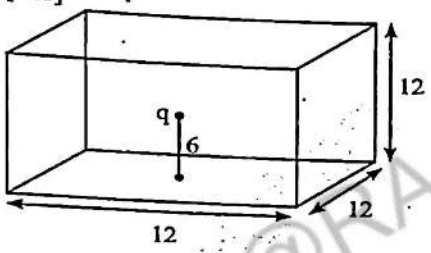
Hence, statement-I is true :
Electric field in region $(r < R)$



$\vec{E} = \frac{1}{4\pi\varepsilon_0} \times \frac{Qr}{R^3}$

$\therefore$ The electric field due to the charged solid sphere at a distance r from the centre is non-zero.
As change encloses within the gaussian surface is equal to zero such as.
$\phi = \oint \vec{E} \cdot \vec{ds} = 0$
Hence, Statement-II is false:

104. [226]



$\phi = \frac{q}{6\varepsilon_0} = \frac{12\mu C}{6\varepsilon_0} = 226 \times 10^3 Nm^2/c$

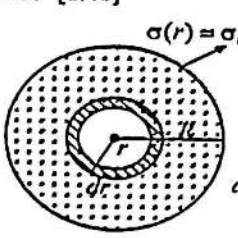
105. [4] Using gauss law
$\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\varepsilon_0} \Rightarrow \vec{\nabla} \cdot (\varepsilon_0 \vec{E}) = \rho \Rightarrow \vec{\nabla} \cdot \vec{D} = \rho$
$\Rightarrow \left(\frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}\right) \cdot (e^{-x} \sin y\hat{i} - e^{-x} \cos y\hat{j} + 2z\hat{k}) = \rho$
$\Rightarrow \rho = -e^{-x} \sin y + e^{-x} \sin y + 2$
At origin $x = 0, y = 0$
$\therefore e = -0 + 0 + 2 = 2$
Hence charge $= eV$
$= 2\,(2 \times 10^{-9}) = 4 \times 10^{-9} = 4$ nC

106. [1] $\frac{\phi_1}{\phi_2} = \frac{\frac{3}{5}E_0 \times 0.2}{\frac{4}{5}E_0 \times 0.3} = \frac{1}{2} \Rightarrow a = 1$

107. [640] $\phi = \left(\frac{2}{5}E_0 \times 0.4\right) = 640 Nm^2C^{-1}$

108. [–48] Flux via $ABCD$
$\phi_1 = \int \vec{E} \cdot d\vec{A} = 0$
Flux via BCEF
$\phi_2 = \vec{E} \cdot \vec{A} = (4x\hat{i} - (y^2+1)\hat{j}) \cdot 4\hat{i} = 16x$ (At $x = 3$)
$\phi_2 = 48 \frac{N.m^2}{C}$;
$\phi_1 - \phi_2 = -48 \frac{N.m^2}{C}$

109. [6.40]



$dq = \sigma_0\left(1 - \frac{r}{R}\right) 2\pi r dr$

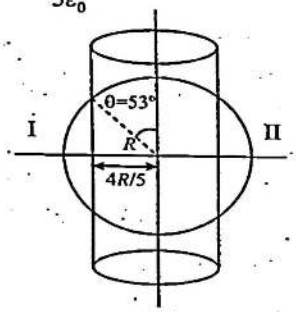
$\phi_0 = \frac{\int dq}{\varepsilon_0} = \frac{\int_0^R \sigma_0\left(1 - \frac{r}{R}\right) 2\pi r\, dr}{\varepsilon_0}$

$\phi = \frac{\int dq}{\varepsilon_0} = \frac{\int_0^{R/4} \sigma_0\left(1 - \frac{r}{R}\right) 2\pi r\, dr}{\varepsilon_0}$

$\therefore \frac{\phi_0}{\phi} = \frac{\sigma_0 2\pi \int_0^R \left(r - \frac{r^2}{R}\right) dr}{\sigma_0 2\pi \int_0^{R/4} \left(r - \frac{r^2}{R}\right) dr}$

$= \frac{\frac{R^2}{2} - \frac{R^3}{3R}}{\frac{R^2}{32} - \frac{R^3}{3 \times 64R}} = \frac{32}{5} = 6.40$

110. (a,b,d)
For option (a), cylinder encloses the shell, thus option is correct
For option (b),
cylinder perfectly enclosed by shell,
thus $\phi = 0$, so option is correct.
for option (c)
$\phi = \frac{2 \times Q}{2\epsilon_0}(1 - \cos 53°) = \frac{2Q}{5\varepsilon_0}$
For option (d):
Charge enclosed by cylinder
$= q = 2 \times 2\pi (1 - \cos 37°) \frac{Q}{4\pi} = \frac{Q}{5}$
$\therefore \phi = \frac{Q}{5\varepsilon_0}$



@TAKE_CBSE_X @RAJ_EDUNET

1. (c) For q (positive charge): The displacement leads to a restoring force that attempts to bring the charge back to the equilibrium position, resulting in simple harmonic motion.
For $-q$ (negative charge): The displacement increases the force in the direction of displacement itself, leading to a motion that does not return the charge to its starting position and hence, is not simple harmonic motion.

2. (d) $qE = mg$ ...(i)

$6\pi\eta r v = mg$ ...(ii)

$\frac{4}{3}\pi r^3 \rho g = mg$

$\therefore r = \left(\frac{3mg}{4\pi\rho g}\right)^{1/3}$ ...(iii)

Substituting the value of r in Eq. (ii) get

$6\pi\eta v\left(\frac{3mg}{4\pi\rho g}\right)^{1/3} = mg$

or $(6\pi\eta v)^3\left(\frac{3mg}{4\pi\rho g}\right) = (mg)^3$

Again substituting $mg = qE$ we get,

$(qE)^2 = \left(\frac{3}{4\pi\rho g}\right)(6\pi\eta v)^3$

or $qE = \left(\frac{3}{4\pi\rho g}\right)^{1/2}(6\pi\eta v)^{3/2}$

$q = \frac{1}{E}\left(\frac{3}{4\pi\rho g}\right)^{1/2}(6\pi\eta v)^{3/2}$

Substituting the given values we get,

$q = 8.0 \times 10^{-19} C$

3. (b) $Q \quad q \quad Q$

Since, q is at the centre of two charges Q and Q, net force on it is zero, whatever the magnitude and sign of charge on it. For the equilibrium of Q, q should be negative because other charge Q will repel it, so q should attract it. At the same time, these attractions and repulsions should be equal.

$\frac{1}{4\pi\varepsilon_0}\frac{QQ}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{(r/2)^2}$

or $q = \frac{Q}{4}$ or with sign $q = -\frac{Q}{4}$

4. (d) If at any time charge Q is at a distance x from O. Net force on charge Q

$F_{net} = F\cos(\theta) + F\cos(\theta)$

$= 2F\cos(\theta)$

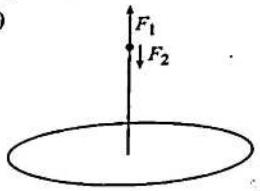
$= \frac{2kqQ}{a^2 + x^2} \times \frac{x}{\sqrt{a^2 + x^2}}$

$= \frac{2kqQx}{(a^2 + x^2)^{3/2}}$

The net force (F_{net}) is directly proportional to the displacement x, but the dependence of the force on $(a^2 + x^2)^{3/2}$ makes it non-linear.

While the charge Q will indeed oscillate about the center due to the restoring nature of this force, the motion is not simple harmonic (SHM) because the force is not directly proportional to $-x$. In SHM, the force should be of the form $F = -kx$. Here, the additional dependence on x via $(a^2 + x^2)^{3/2}$ complicates this relationship.

5. (a, c, d)



$\vec{F}_1 = q\left(\frac{-dv}{dz}\right) = \frac{q\sigma}{2\epsilon_0}\left(1 - \frac{z}{\sqrt{R^2 + Z^2}}\right)\hat{k}$

$\vec{F}_2 = -c\hat{k}$

$\beta = \frac{1}{4}$

$\therefore \frac{1}{4} = \frac{2c\varepsilon_0}{q\sigma}$ (Given)

$\frac{q\sigma}{2\varepsilon_0} = 4c$ ...(i)

For equilibrium at $z = Z_0$

$F_{net} = F_1 + F_2$

$\therefore F_1 = F_2 \Rightarrow \frac{q\sigma}{2\varepsilon_0}\left(1 - \frac{Z}{\sqrt{R^2 + Z^2}}\right) = c$

from equation (i)

$\Rightarrow \left(1 - \frac{Z}{\sqrt{R^2 + Z^2}}\right) = \frac{1}{4}$

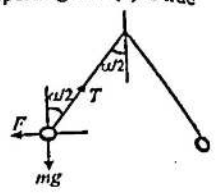
$\Rightarrow \frac{Z}{\sqrt{R^2 + Z^2}} = \frac{3}{4}$

$\Rightarrow Z = \sqrt{\frac{9}{7}}R = 1.13R$

$Z > 1.13\ R$; $F_2 > F_1$ the restoring force dominates, and the particle moves towards the origin.

$Z < 1.13\ R$; $F_1 > F_2$ the electrostatic force dominates, pulling the particle back towards its initial position.

6. (b, c) The electric force between the spheres reduces in a dielectric medium since the force is inversely proportional to the dielectric constant (κ). Hence, (a) is false. the electric force reduces, supporting that (b) is true



In equilibrium,

$T\cos\frac{\alpha}{2} = mg$ and $T\sin\frac{\alpha}{2} = F$

After immersed in dielectric liquid. As given no change in angle α.

So $T\cos\frac{\alpha}{2} = mg - V\rho g$

when $\rho = 800$ Kg/m^3

and $T\sin\frac{\alpha}{2} = \frac{F}{\varepsilon_r}$ $\therefore \frac{mg}{F} = \frac{mg - V\rho g}{\frac{F}{\varepsilon_r}}$

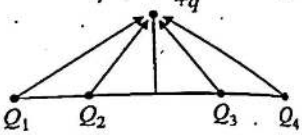
$\frac{1}{\varepsilon_r} = 1 - \frac{\rho}{d}$

d = density of sphere

$\frac{1}{21} = 1 - \frac{800}{d}$

$d = 840$ kgm^{-3}

7. (a) Case 1- when all charges are positive.



From the figure, it is clear that the horizontal components of the force due to Q_1 will cancel with Q_4 and Q_2 will cancel with Q_3. The vertical components will add up and hence the net force will be in $+y$ direction. So P-1

Case 2: When Q_3, Q_4 negative and Q_1, Q_2 positive: In this case, it is clear from the diagram that the vertical component of the force due to Q_1 will cancel with Q_4 and Q_2 will cancel with Q_3. The horizontal components will add up giving rise to a net force in the positive x direction.

So Q-1

@TAKE CBSE X @RAJ_EDUNET

Case 3- When Q_1, Q_4 are positive and Q_2, Q_3 are negative: In this case, the horizontal components of the forces of the same magnitude will cancel each other. However, the net vertical component due to the resultant of force due to Q_1 and Q_4 will be less than the vertical component due to the resultant of the forces due to Q_2 and Q_3, (due to larger distance of Q_1q). So there will be a net force in the $-y$ direction.

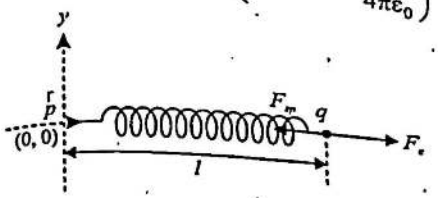
So R-4 is correct.

Case 4- when Q_1, Q_3 positive and Q_2, Q_4 negative, then the net force will be in the $-x$ direction. So option (a) is correct.

8. [3.14] Electrostatic force = Spring force

At 1, $Fe = F_{sp}, kl = \dfrac{2\alpha pq}{l^3}$

$\left(\text{Here } \alpha = \dfrac{1}{4\pi\varepsilon_0}\right)$



Now, the mass m is displaced by $\Delta l = x$ from the mean position.

$$F_{net} = F_{sp} - F_e = k(l+x) - \frac{q(2\alpha p)}{(l+x)^3}$$

$$= k(x+l) - \frac{q(2\alpha p)}{l^3(l+x/l)^3}$$

$$= kx + kl - q\left(\frac{2\alpha p}{l^3}\right)\left(1 - \frac{3x}{l}\right)$$

$$= kx + kl - q\left(\frac{2\alpha p}{l^3}\right) + \frac{2\alpha pq}{l^3}\cdot\frac{3x}{l}$$

Substituting $\dfrac{2\alpha pq}{l^3} = kl$, we get

$$F_{net} = kx + kl\left(\frac{3x}{l}\right) = 4kx$$

This is restoring in nature.

Hence,

or $T = 2\pi\sqrt{\dfrac{m}{4k}} = \pi\sqrt{\dfrac{m}{k}}$ $\therefore f = \dfrac{1}{\pi}\sqrt{\dfrac{k}{m}}$

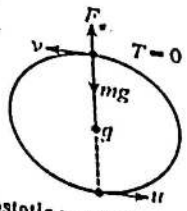
So, $\delta = \pi = 3.14$

9. [5.86] Given : $q = 1\mu C = 10^{-6}\ C$

$m = 2 \times 10^{-3}$ kg and $l = 0.8$m

Let u be the speed of the particle at its lowest point and v its speed at highest point.

At highest point three forces are acting on the particle.



(a) Electrostatic repulsion

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{l^2} \text{ (outwards)}$$

(b) Weight, $w = mg$ (inwards)

(c) Tension T (inwards)

$T = 0$, if the particle has just to complete the circle and the necessary centripetal force is provided by $w - F_e$ i.e.

$$\frac{mv^2}{l} = w - F_e$$

or $v^2 = \dfrac{l}{m}\left(mg - \dfrac{1}{4\pi\varepsilon_0}\dfrac{q^2}{l^2}\right)$

$$v^2 = \frac{0.8}{2\times10^3}\left(2\times10^{-3}\times10 - \frac{9.0\times10^9\times(10^{-6})^2}{(0.8)^2}\right)$$

or $v^2 = 2.4\ m^2/s^2$ ...(i)

Now, the electrostatic potential energy at the lowest and highest points are equal. Hence, from conservation of mechanical energy. Increase in gravitational potential energy = Decrease in kinetic energy.

or $mg(2l) = \dfrac{1}{2}m(u^2 - v^2)$

or $u^2 = v^2 + 4gl$

Substituting the values of v^2 from Eq. (i), we get

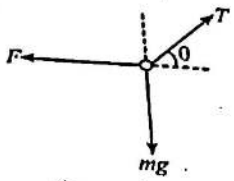
$u^2 = 2.4 + 4(10)(0.8) = 34.4\ m^2/s^2$

$\therefore\ u = 5.86$ m/s

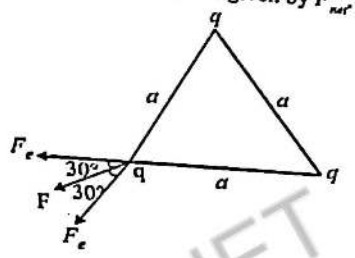
Therefore, minimum horizontal velocity imparted to the lower ball, so that it can make complete revolution, is 5.86 m/s.

10. [False] The vertical components of the force due to each differential element of the ring will cancel out in pairs. However, the horizontal components will not cancel out and will result in an external force in the x-direction. So the particle will execute oscillatory motion, but it is not SHM because the condition of $x << R$ is not satisfied here. Here $x = 2R$ and Radius $= R$ are comparable. So the statement is False.

11.



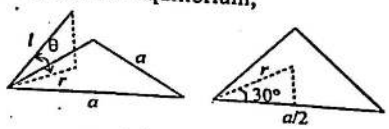
the resultant of electrostatic forces between two charges is given by F_{net}



$F_{net} = 2F_e\cos30°$; where $\cos30° = \dfrac{\sqrt{3}}{2}$

$$= 2\left[\frac{1}{4\pi\epsilon}\cdot\frac{q^2}{a^2}\right]\frac{\sqrt{3}}{2} = \sqrt{3}\times10^{13}q^2$$

Where θ is the angle of string with horizontal in equilibrium,



$\cos\theta = \dfrac{r}{l} = \dfrac{(a/2)\sec30°}{l} = \dfrac{a}{\sqrt{3}l} = \dfrac{3}{100\sqrt{3}}$

So, $\theta \approx 89°$

Here, the particle is in equilibrium under three concurrent forces, F, T and mg. So, by using Lami's theorem,

$$\frac{F}{\sin(90°+\theta)} = \frac{mg}{\sin(180°-\theta)}$$

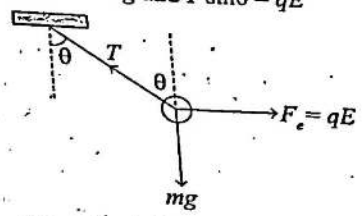
or $\sqrt{3}\times10^{13}q^2 = (1\times10^{-3})(10)\cot89°$

On solving, we have

$q = 0.317\times10^{-8}\ C$ or $q = 3.17\times10^{-9}$ C

12. For equilibrium of bob

$T\cos\theta = mg$ and $T\sin\theta = qE$



From these two equations we find

$T = \sqrt{(mg)^2 + (qE)^2}$

and $\theta = \tan^{-1}\left(\dfrac{qE}{mg}\right)$

@FAKE_CBSE_BY_GRAJ_EDUNET

Substituting the values we have

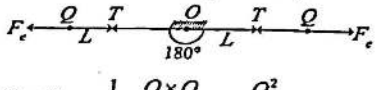
$$T=\sqrt{(80\times10^{-6}\times9.8)^2+(2\times10^{-8}\times20000)^2}$$

$$=8.79\times10^{-4}N$$

$$\theta=\tan^{-1}\left(\frac{2\times10^{-8}\times20000}{80\times10^{-6}\times9.8}\right)=27°$$

13. Force on $-q$ due to charges at 1 and 4 are equal and opposite. Similarly, forces on $-q$ due to charges at 2 and 5 are also equal and opposite. Therefore, net force on $-q$ due to charges at 1, 2, 4 and 5 is zero. Only unbalanced force is between $-q$ and $+q$ at 3 which is equal to $\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{L^2}$ or $9.0\times10^9\frac{q^2}{L^2}$. (attraction)

14. Due to electrostatic repulsion the charges will move as farthest as possible and the angle between the two strings will be 180° as shown in figure. Tension in each string will be equal to the electrostatic repulsion between the two charges. Thus,



$$T=F_e=\frac{1}{4\pi\varepsilon_0}\frac{Q\times Q}{(2L)^2}=\frac{Q^2}{16\pi\varepsilon_0L^2}$$

15. (*b*) **List-II**

(P) $E=\frac{1}{4\pi\varepsilon_0}\frac{Q}{d^2}\Rightarrow E\propto\frac{1}{d^2}$

(Q) $E_{axis}=\frac{1}{4\pi\varepsilon_0}\frac{2Q(2l)}{d^3}\Rightarrow E\propto\frac{1}{d^3}$

(R) $E=\frac{\lambda}{2\pi\varepsilon_0 d}\Rightarrow E\propto\frac{1}{d}$

(S) $E=\frac{\lambda}{2\pi\varepsilon_0(d-l)}-\frac{\lambda}{2\pi\varepsilon_0(d+l)}$

$=\frac{\lambda(2l)}{2\pi\varepsilon_0 d^2}\Rightarrow E\propto\frac{1}{d^2}$

(T) $E=\frac{\sigma}{2\varepsilon_0}\Rightarrow E$ is independent of d

16. Force on a charged particle is along the tangent of electric line of force. A particle does not always move in the direction of force acting on it. Projective motion and the circular motion are the best examples.

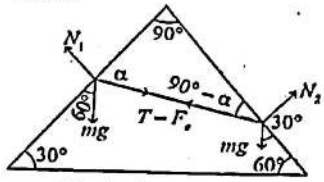
17. (*a*) Tension and electrostatic force are in opposite directions and along the string. Now each bead is in equilibrium under three concurrent forces

(*i*) Normal reaction (N)

(*ii*) Weight (mg) and

(*iii*) $T-F_e$, where $F_e=\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1q_2}{l^2}$

Applying Lami's theorem for both beads.



$$\frac{N_1}{\sin(180°-\alpha)}=\frac{mg}{\sin(90°+\alpha)}=\frac{T-F_e}{\sin(90°+60°)}\quad\ldots(i)$$

For bead q_2

$$\frac{N_2}{\sin(60°+\alpha)}=\frac{mg}{\sin(180°-\alpha)}=\frac{T-F_e}{\sin(90°+30°)}\quad\ldots(ii)$$

Dividing Eq. (*i*) by Eq. (*ii*), we have

$$\tan\alpha=\frac{\cos30°}{\cos60°}=\sqrt{3}\Rightarrow\alpha=60°$$

$$T=F_e+mg=\left(\frac{1}{4\pi\varepsilon_0}\right)\cdot\frac{q_1q_2}{l^2}+mg\quad\ldots(iii)$$

$N_1=\sqrt{3}\,mg$ and $N_2=mg$

From Eq. (*iii*) T = 0 when string is cut.

or $q_1q_2=-(4\pi\varepsilon_0)\,mgl^2$

18. (*c*) Given : $E_1(r_0)=E_2(r_0)=E_3(r_0)$

Here $E_1(r)=\frac{Q}{4\pi\epsilon_0 r^2}$,

$E_2(r)=\frac{2\lambda}{4\pi\epsilon_0 r}$, $E_3(r)=\frac{\sigma}{2\epsilon_0}$

From $E_1(r_0)=E_3(r_0)$

$\Rightarrow\frac{Q}{4\pi\epsilon_0 r_0^2}=\frac{\sigma}{2\epsilon_0}\Rightarrow Q=2\sigma\pi r_0^2$

So option (*a*) is wrong.

From $E_2(r_0)=E_3(r_0)$

$\Rightarrow\frac{2\lambda}{4\pi\epsilon_0 r_0}=\frac{\sigma}{2\epsilon_0}\Rightarrow r_0=\frac{\lambda}{\pi\sigma}$

So option (*b*) is wrong.

And $Q=2\lambda r_0$

$E_2(r_0/2)=\frac{4\lambda}{4\pi\epsilon_0 r_0}$

$E_1(r_0/2)=\frac{4Q}{4\pi\epsilon_0 r_0^2}=\frac{8\lambda}{4\pi\epsilon_0 r_0}$

$=2E_2(r_0/2)$

So option (*c*) is correct.

$E_3(r_0/2)=\frac{\sigma}{2\epsilon_0}\Rightarrow\frac{E_2(r_0/2)}{E_3(r_0/2)}=\frac{2\lambda}{\pi\sigma r_0}$

$=2$

$E_2(r_0/2)=2E_3(r_0/2)$

So option (*d*) is wrong.

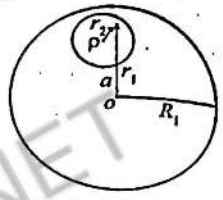
19. (*c*) $E_1=\frac{kQ}{R^2}$, where $k=\frac{1}{4\pi\varepsilon_0}$

$\Rightarrow E_2=\frac{k(2Q)}{R^2}\Rightarrow E_2=\frac{2kQ}{R^2}$

$\Rightarrow E_3=\frac{k(4Q)R}{(2R)^2}\Rightarrow E_3=\frac{kQ}{2R^2}$

$\therefore E_2>E_1>E_3$

20. (*d*) The problem can be considered as a superposition of electric field E due to the larger sphere without the cavity and a smaller sphere with opposite charge density.



Inside a spherical charge distribution for an internal point $E(r)=\frac{\rho r}{3\varepsilon_r}$ which is a result of the application of Gauss's law.

Let the vector to the point P inside the cavity be $\vec{r}_1$ taking origin at the center of the large sphere and $\vec{r}_2$ be the vector from center ρ' of the smaller sphere.

$\therefore\ \vec{E}=\frac{\rho\vec{r}_1}{3\varepsilon_0}+\left(\frac{-\rho\vec{r}_2}{3\varepsilon_0}\right)$

$=\frac{\rho}{3\varepsilon_0}(\vec{r}_1-\vec{r}_2)=\frac{\rho}{3\varepsilon_0}\vec{a}$

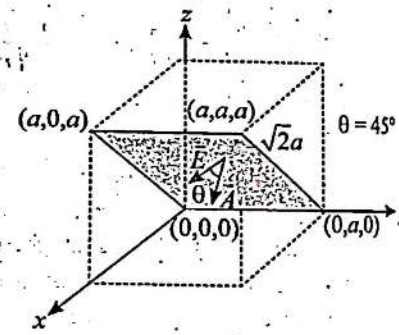
where $\vec{a}$ is the vector joining the centers O and ρ of the large and small spheres which is a constant vector.

The electric field is uniform both in magnitude and direction.

21. (*c*) Flux through area = Electric field × Area projected

$\phi=EA\cos45°$

$=E_0\left(\sqrt{2}a^2\right)\times\frac{1}{\sqrt{2}}=E_0a^2$



@FREE_CBSE_X_@RAJ_EDUNET

22. (b) For Shell 1: $\sigma = \frac{Q_1}{4\pi R^2}$

For Shell 2: $\sigma = \frac{Q_1 + Q_2}{16\pi R^2}$

For Shell 3: $\sigma = \frac{Q_1 + Q_2 + Q_3}{36\pi R^2}$

Since the surface charge densities are equal:

$$\frac{Q_1}{4\pi R^2} = \frac{Q_1 + Q_2}{16\pi R^2} = \frac{Q_1 + Q_2 + Q_3}{36\pi R^2}$$

Equation for Shell 1 and Shell 2:

$$\frac{Q_1}{4\pi R^2} = \frac{Q_1 + Q_2}{16\pi R^2}$$

$Q_2 = 3Q_1$

Equation for Shell 2 and Shell 3:

$$\frac{Q_1 + Q_2}{16\pi R^2} = \frac{Q_1 + Q_2 + Q_3}{36\pi R^2}$$

$(Q_1 + Q_2).36\pi R^2 = (Q_1 + Q_2 + Q_3).16\pi R^2$

$36(Q_1 + Q_2) = 16(Q_1 + Q_2 + Q_3)$

Substitute $Q_2 = 3Q_1$:

we get,

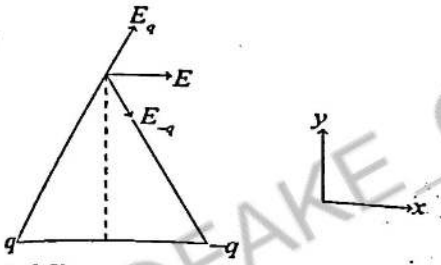
$Q_3 = 5Q_1$

Hence,

The ratio of charges on the shells is:

$Q_1 : Q_2 : Q_3 = 1 : 3 : 5$

23. (c)



The electric field E at all points on the x-axis will not have the same direction.

For $-d \le x \le d$, electric field is along positive x-axis while for all other points it is along negative x-axis.

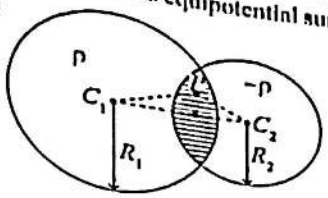
The electric field E at all points on the y-axis will be parallel to the x-axis (i.e. $\hat{i}$).

The electric potential at the origin due to both the charges is zero, hence, no work is done in bringing a test charge from infinity to the origin.

Dipole moment is directed from the $-q$ charge to the $+q$ charge (i.e. $-\hat{i}$ direction).

24. (d) Electric field lines never enter a metallic conductor ($E = 0$, inside a conductor) and they fall normally on the surface of a metallic conductor (because whole surface is at same potential and lines are perpendicular to equipotential surface).

25. (c, d)



$$E_1 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{R^3}\vec{r} = \frac{1}{3\varepsilon_0}\left(\frac{q}{\frac{4}{3}\pi R^3}\right)\vec{r}$$

$$= \frac{\rho}{3\varepsilon_0}\vec{r} = \frac{\rho}{3\varepsilon_0}\overrightarrow{C_1P}$$

$$\therefore E_P = E_1 + E_2 = \frac{\rho}{3\varepsilon_0}\overrightarrow{C_1P} + \frac{(-\rho)}{3\varepsilon_0}\overrightarrow{C_2P}$$

$$= \frac{\rho}{3\varepsilon_0}\left(\overrightarrow{C_1P} + \overrightarrow{PC_2}\right)$$

$$E_P = \frac{\rho}{3\varepsilon_0}\overrightarrow{C_1C_2}$$

$\therefore E_P$ = constant

26. (a,c) Total charge inside the CUBE

$$= \frac{3q - q - q}{\varepsilon_0}$$

$\phi = q/\varepsilon_0$

ϕ through any surface of the cube $= \frac{q}{6\varepsilon_0}$

$\phi_{x=(+a/2)} = \phi_{x=(-a/2)} = \phi_{y=(a/2)} = \phi_{y=(-a/2)} = \phi_{z=(-a/2)}$

27. (a, d) From the behaviour of electric lines, we can say that Q_1 is positive and Q_2 is negative. Further, $|Q_1| > |Q_2|$

At some finite distance to the right of Q_2, electric field will be zero. Because electric field due to Q_1 is towards right (away from Q_1) and due to Q_2 is towards left (towards Q_2). Since magnitude of Q_1 is more, the two fields may cancel each other because distance of that point from Q_1 will also be more.

$\therefore$ The correct options are (a) and (d).

28. (a,c) Inside the sphere $E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{R^3}\vec{r}$

$\Rightarrow E \propto r$ for $r \le R$

i.e. E at centre = 0 as r = 0 and E at surface

$$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{R^2}$$

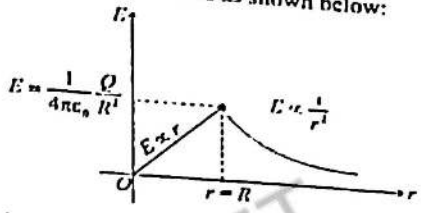
as $r = R$

Outside the sphere

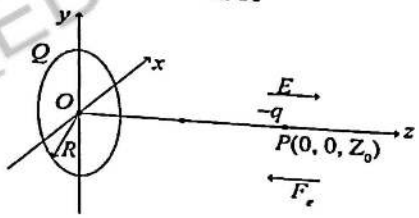
$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r^2} \text{ for } r \ge R$$

or $E \propto \frac{1}{r^2}$

Variation of electric field (E) with distance (r) from the centre is as shown below:



29. (a, c) Let Q be the charge on the ring, the negative charge $-q$ is released from point P $(0, 0, z_0)$. The electric field at P due to the charged ring will be along positive z-axis and its magnitude will be



$$E = \frac{1}{4\pi\varepsilon_0}\frac{Qz_0}{(R^2 + z_0^2)^{3/2}}$$

$E = 0$, at centre of the ring because $z_0 = 0$

Force on charge at P will be towards centre as shown, and its magnitude is

$$F_e = qE = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qq}{(R^2 + z_0^2)^{3/2}}\cdot z_0 \quad ...(i)$$

Similarly, when it crosses the origin, the force is again towards centre O.

Thus, the motion of the particle is periodic for all values of z_0 lying between 0 and ∞.

Secondly, if $z_0 << R$, $(R^2 + z_0^2)^{3/2} \approx R^3$

$$F_e \approx \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qq}{R^3}\cdot z_0$$ [From Eq. (i)]

i.e. the restoring force $F_e \propto -z_0$. Hence, the motion of the particle will be simple harmonic. (Here negative sign implies that the force is towards its mean position O, where E is zero, so force on $-q$ is zero.)

30. [True] When X-rays fall on the metal ball, some electrons emit from it due to photoelectric effect. The ball thus gets positively charged and on a positively charged ball an electrostatic force in the direction of electric field acts. Due to this force ball gets deflected in the direction of electric field.

@FAKE_CBSE_X@RAJ_EDUCATION

31. [6] The magnitude of the electric field at the point P which is at a distance $2R$ from the axis of the cylinder

$$E = E_{total} - E_{cavity}$$

$$= \frac{\gamma}{2\pi\varepsilon_0(2R)} - \frac{1}{4\pi\varepsilon_0}\frac{Q}{(2R)^2}$$

$$Q_{sphere} = \frac{4}{3}\pi\left(\frac{R}{2}\right)^3\rho = \frac{\pi R^3\rho}{6}$$

$$\lambda_{cylinder} = \pi R^2\rho$$

$$\therefore E = \frac{\pi R^2\rho}{4\pi\varepsilon_0 R} - \frac{1}{4\pi\varepsilon_0}\cdot\frac{\pi R^3\rho/6}{4R^2}$$

$$= \frac{23\rho R}{96\varepsilon_0} = \frac{23\rho R}{16\times 6\times\varepsilon_0}$$

$$\therefore k = 6$$

32. (*a*) According to Gauss law of electrostatics,

$$\oint E\cdot dS = \frac{q_{enclosed}}{\varepsilon_0}$$

From the graph, it is clear that for $a < R$, the charge density is independent of a. So the electric field at $r = R$ will be independent of a as the material within it has a charge density independent of a and thus the q enclosed will be independent of a.

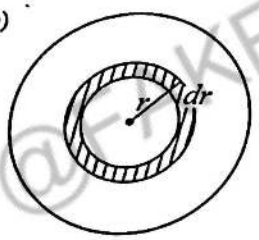
33. (*a*) Total enclosed charge as already shown is

$$q_{net} = \frac{6C}{2} + \frac{8C}{4} - 7C = -2C$$

From Gauss-theorem, net flux,

$$\phi_{net} = \frac{q_{net}}{\varepsilon_0} = \frac{-2C}{\varepsilon_0}$$

34. (*b*)



Consider a spherical shell with radius r and thickness dr

$$dQ = \rho\times 4\pi r^2 dr$$

Also, $\rho = \dfrac{d(R-r)}{R}$

As $\rho \propto \dfrac{1}{R}$ and $d \propto \dfrac{1}{R-r}$

Total charge,

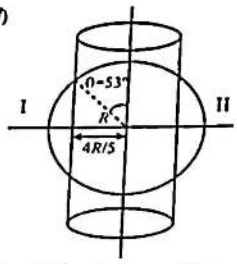
$$Q = Ze = \int_0^R \frac{d(R-r)}{R}\cdot 4\pi r^2 dr$$

$$Q = \frac{4\pi d}{R}\left[\int_0^R Rr^2 dr - \int_0^R r^3 dr\right] = Ze$$

Or $\dfrac{4\pi d}{R}\left[\dfrac{R^4}{3} - \dfrac{R^4}{4}\right] = Ze$

$$d = \frac{3Ze}{\pi R^3}$$

35. (*a,b,d*)



For option (*a*), cylinder encloses the shell, thus option is correct

For option (*b*),

cylinder perfectly enclosed by shell, thus $\phi = 0$, so option is correct.

for option (*c*)

$$\phi = \frac{2\times Q}{2\,\epsilon_0}(1-\cos 53°) = \frac{2Q}{5\varepsilon_0}$$

For option (*d*):

Charge enclosed by cylinder

$$= q = 2\times 2\pi(1-\cos 37°)\frac{Q}{4\pi} = \frac{Q}{5}$$

$$\therefore \phi = \frac{Q}{5\varepsilon_0}$$

36. (*a,b*) According to Gauss's law, $\phi = \dfrac{q_{en}}{\varepsilon_0}$

$$PQ = 2R\sin 60°$$

$$q_{en} = \lambda\times PQ = 2\lambda R\sin 60° = \sqrt{3}R\lambda$$

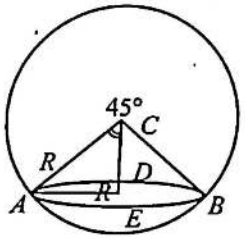
$$\phi = \frac{\sqrt{3}R\lambda}{\varepsilon_0}$$

Electric field of infinitely long wire

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}\times\hat{n}$$

Electric field will be perpendicular to the length of the wire and away from it. The z-component of the electric field is zero at all points on surface of shell.

37. (*a, d*) Flux passing through curved surface and flat surface will be same and flux passing through flat surface can be obtained by the method discussed below.



Area of spherical surface ACB

$S = 2\pi R^2(1-\cos\theta)$, where $\theta = 45°$

$$\therefore S = 2\pi R^2\left(1-\frac{1}{\sqrt{2}}\right)$$

Now flux passing through $AEBD$ and ACB will be same.

Flux passing through whole sphere is $\dfrac{Q}{\varepsilon_0}$.

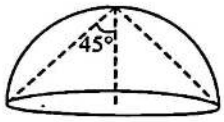
Therefore flux passing through surface ACB would be, $\phi = \left[\dfrac{(Q/\varepsilon_0)}{4\pi R^2}\right]\left[2\pi R^2\left(1-\dfrac{1}{\sqrt{2}}\right)\right]$

$$= \frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$$

NOTE There is no proper logic of negative sign but IIT website has given (*a*) option also correct.

(*b*) The component of the electric field perpendicular to the flat surface will decrease as we move away from the centre as the distance increases (magnitude of electric field decreases) as well as the angle between the normal and electric field will increase. Hence, the component of the electric field normal to the flat surface is not constant.

(*c*) Total flux ϕ due to charge Q is $\dfrac{Q}{\varepsilon_0}$.



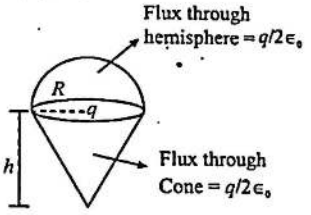
So, ϕ through the curved and flat surface will be less than $\dfrac{Q}{\varepsilon_0}$.

(*d*) Since, the circumference is equidistant from Q it will be equipotential $V = \dfrac{kQ}{\sqrt{2}R}$

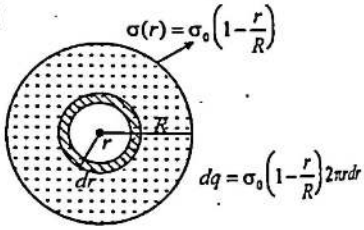
Where, $k = \dfrac{1}{4\pi\varepsilon_0}$

38. [3] Flux through cone $= \dfrac{q}{2\,\epsilon_0} = \dfrac{nq}{6\,\epsilon_0}$

$\Rightarrow n = 3$



39. [6.40]



@FAKE_CBSE_X @RAJ_EDUCATION

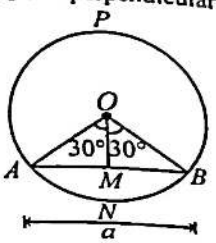
$$\phi_0 = \frac{\int dq}{\varepsilon_0} = \frac{\int_0 \sigma_0\left(1-\frac{r}{R}\right)2\pi r\,dr}{\varepsilon_0}$$

$$\phi = \frac{\int dq}{\varepsilon_0} = \frac{\int_0^{R/4} \sigma_0\left(1-\frac{r}{R}\right)2\pi r\,dr}{\varepsilon_0}$$

$$\therefore \frac{\phi_0}{\phi} = \frac{\sigma_0 2\pi\int_0^{R}\left(r-\frac{r^2}{R}\right)dr}{\sigma_0 2\pi\int_0^{R/4}\left(r-\frac{r^2}{R}\right)dr}$$

$$= \frac{\frac{R^2}{2}-\frac{R^3}{3R}}{\frac{R^2}{32}-\frac{R^3}{3\times 64R}} = \frac{32}{5} = 6.40$$

40. [6] $ANBP$ is cross-section of a cylinder of length L. The line charge passes through the centre O and perpendicular to paper.



$$AM = \frac{a}{2}, MO = \frac{\sqrt{3}a}{2}$$

$$\therefore \angle AOM = \tan^{-1}\left(\frac{AM}{OM}\right) = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right) = 30°$$

Electric flux passing from the whole cylinder $\phi_1 = \frac{q_{in}}{\varepsilon_0} = \frac{\lambda L}{\varepsilon_0}$

$\therefore$ Electric flux passing through $ABCD$ plane surface (shown only AB) = Electric flux passing through cylindrical surface $ANB = \left(\frac{60°}{360°}\right)(\phi_1) = \frac{\lambda L}{6\varepsilon_0}$

$\therefore n = 6$

41. [2] From gauss law,

$$\oint E\cdot dA = \frac{1}{\varepsilon_0}\int \rho dV = \frac{1}{\varepsilon_0}\int_0^R kr^a 4\pi r^2 dr$$

$$E_1 = \frac{kR^{(a+3)}}{\varepsilon_0(a+3)},\ E_2 = \frac{k(R/2)^{(a+3)}}{\varepsilon_0(a+3)}$$

(for $r = R/2$)

$$E_2 = E_{1/8} \Rightarrow \left(\frac{1}{2}\right)^{a+3} = \frac{1}{8}$$

$$\Rightarrow \left(\frac{1}{2}\right)^{a+3} = \left(\frac{1}{2}\right)^3$$

On equating the base, $a = 2$

42. (b, c) $a_y = -400\sqrt{3}\times 10^{10}$ $[qE_y = ma_y]$

$$R = 5 = \frac{40\times 10^{12}\sin 2\theta}{400\sqrt{3}\times 10^{10}}$$

$$\left[R(\text{range}) = \frac{u^2\sin 2\theta}{a_y}\right]$$

$$\sin 2\theta = \frac{\sqrt{3}}{2}$$

$\Rightarrow 2\theta = 60°, 120 \Rightarrow \theta = 30°, 60°$

Time of flight,

$$T_1 = \frac{2\times 2\sqrt{10}\times 10^6 \times \frac{1}{2}}{400\sqrt{3}\times 10^{10}} = \sqrt{\frac{5}{6}}\mu s$$

(for $\theta = 30°$)

Time of flight,

$$T_2 = \frac{2\times 2\sqrt{10}\times 10^6 \times \frac{\sqrt{3}}{2}}{400\sqrt{3}\times 10^{10}} = \sqrt{\frac{5}{3}}\mu s$$

(for $\theta = 60°$)

43. (c) For electron

$$a_e = \frac{F}{m_e},\ d = \frac{1}{2}a_e t_1^2 \Rightarrow t_1^2 = \frac{2d}{a_e} = 2d\frac{m_e}{F}$$

Hence, for proton,

$$a_p = \frac{F}{m_p},\ d = \frac{1}{2}a_p t_2^2$$

$$\Rightarrow t_2^2 = \frac{2d}{a_p} = 2d\frac{m_p}{F}$$

Hence, $\frac{t_2^2}{t_1^2} = \frac{m_p}{m_e} \Rightarrow \frac{t_2}{t_1} = \sqrt{\frac{m_p}{m_e}}$

44. [2] $a = \frac{F}{m} = \frac{qE}{m} = 10^1\sin(10^3 t)$

$$\frac{dv}{dt} = 10^3\sin(10^3 t) \Rightarrow \int_0^v dv = \int_0^t 10^3 \sin(10^3 t)\,dt$$

$$\therefore v = \frac{10^3}{10^3}[1-\cos(10^3 t)]$$

Velocity will be maximum when $\cos(10^3 t) = -1$

$v_{max} = 2$ m/s

45. [False] Electric field lines of force does not represent the path of the charged particle but tangent to the path at any point on the line shows the direction of electric force on it and it is not always necessary that motion of the particle is in the direction of force acting on it. Projectile motion or circular motion is the best example of it.

@FAKE_CBSE_X @RM_EDUNET

18 Electrostatic Potential and Capacitance

Scan for Sol.

JEE-Main

Work done to move change in Electric Field, Electrostatic Potential Energy

1. An electric dipole of dipole moment is 6.0×10^{-6} cm placed in a uniform electric field of 1.5×10^{3} NC^{-1} in such a way that dipole moment is along electric field. The work done in rotating dipole by 180° in this field will be ____ mJ **[8 April, 2023 (Shift-I)]**

2. A point charge of $2 \times 10^{-2}C$ is moved from P to S in a uniform electric field of 30 N/C directed along positive x-axis. If coordinates of P and S are (1, 2, 0) m and (0, 0, 0)m respectively, the work done by electric field will be **[29 Jan, 2023 (Shift-II)]**

   (a) 1200 mJ (b) 600 mJ (c) −600 mJ (d) −1200 mJ

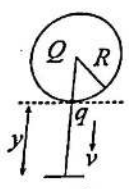
3. 27 similar drops of mercury are maintained at 10 V each. All these spherical drops combine into a single big drop. The potential energy of the bigger drop is ..... times that of a smaller drop. **[26 Feb, 2021 (Shift-II)]**

4. If the potential energy between two molecules is given by $U=-\frac{A}{r^6}+\frac{B}{r^{12}}$, then at equilibrium, separation between molecules, and the potential energy are **[6 Sep, 2020 (Shift-I)]**

   (a) $\left(\frac{2B}{A}\right)^{\frac{1}{6}}, -\frac{A^2}{2B}$ (b) $\left(\frac{B}{2A}\right)^{\frac{1}{6}}, -\frac{A^2}{2B}$

   (c) $\left(\frac{2B}{A}\right)^{\frac{1}{6}}, -\frac{A^2}{4B}$ (d) $\left(\frac{B}{A}\right)^{\frac{1}{6}}, 0$

5. A solid sphere of radius R carries a charge $Q+q$ distributed uniformly over its volume. A very small point like piece of it of mass m gets detached from the bottom of the sphere and falls down vertically under gravity. This piece carries charge q. If it acquires a speed v when it has fallen through a vertical height y (see figure), then (Assume the remaining portion to be spherical). **[5 Sep, 2020 (Shift-I)]**



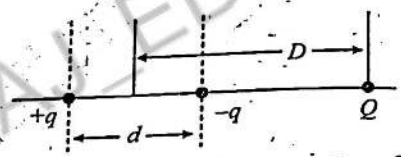
   (a) $v^2 = y\left[\frac{qQ}{4\pi\varepsilon_0 R(R+y)m}+g\right]$

   (b) $v^2 = 2y\left[\frac{qQR}{4\pi\varepsilon_0(R+y)^3 m}+g\right]$

   (c) $v^2 = y\left[\frac{qQ}{4\pi\varepsilon_0 R^2 ym}+g\right]$

   (d) $v^2 = 2y\left[\frac{qQ}{4\pi\varepsilon_0 R(R+y)m}+g\right]$

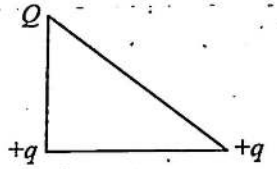
6. A system of three charges are placed as shown in the figure If $D >> d$,the potential energy of the system is best given by **[9 April, 2019 (Shift-I)]**



   (a) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{D^2}\right]$ (b) $\frac{1}{4\pi\varepsilon_0}\left[+\frac{q^2}{d}+\frac{qQd}{D^2}\right]$

   (c) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}+\frac{2qQd}{D^2}\right]$ (d) $\frac{1}{4\pi\varepsilon_0}\left[-\frac{q^2}{d}-\frac{qQd}{2D^2}\right]$

7. Three charges Q, $+q$ and $+q$ are placed at the vertices of a right-angle isosceles triangles as shown below. The net electrostatic energy of the configuration is zero, if the value of Q is **[11 Jan, 2019 (Shift-I)]**



   (a) $\frac{-\sqrt{2}q}{\sqrt{2}+1}$ (b) $+q$ (c) $-2q$ (d) $\frac{-q}{1+\sqrt{2}}$

8. In free space, a particle A of charge 1 μC is held fixed at a point P. Another particle B of the same charge and mass 4 μg is kept at a distance of 1 mm from P. If B is released, then its velocity at a distance of 9 mm from P is

   $\left[\text{Take } \frac{1}{4\pi\varepsilon_0} = 9\times10^9\, Nm^2C^{-2}\right]$ **[10 April, 2019 (Shift-II)]**

   (a) 9..5 × 10^2 m/s (b) 2.0 × 10^3 m/s
   (c) 10..0 m/s (d) 3.0 × 10^4 m/s

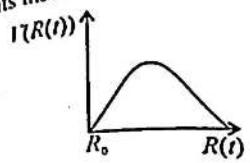
BRAKE_CBSE_@RAJEDUNET

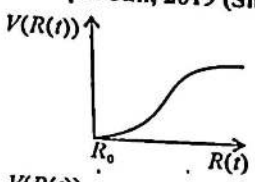
9. Four equal point charges Q each are placed in the xy plane at (0, 2), (4, 2), (4, –2) and (0, – 2). The work required to put a fifth charge Q at the origin of the coordinate system will be **[10 Jan, 2019 (Shift-II)]**

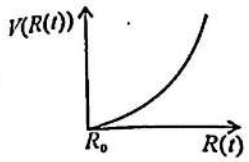
(a) $\frac{Q^2}{2\sqrt{2}\pi\varepsilon_0}$ (b) $\frac{Q^2}{4\pi\varepsilon_0}\left(1+\frac{1}{\sqrt{3}}\right)$

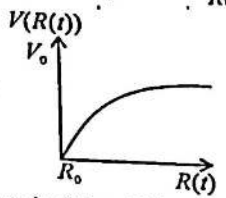
(c) $\frac{Q^2}{4\pi\varepsilon_0}$ (d) $\frac{Q^2}{4\pi\varepsilon_0}\left(1+\frac{1}{\sqrt{5}}\right)$

10. There is a uniform spherically symmetric surface charge density at a distance R_0 from the origin. The charge distribution is initially at rest and starts expanding because of mutual repulsion. The figure that represents best the speed $V(R(t))$ of the distribution as a function of its instantaneous radius $R(t)$ is **[12 Jan, 2019 (Shift-I)]**

(a) 

(b) 

(c) 

(d) 

11. An electric dipole of dipole moment is 6.0×10^{-6} cm placed in a uniform electric field of 1.5×10^3 NC^{-1} in such a way that dipole moment is along electric field. The work done in rotating dipole by 180° in this field will be _____ mJ **[8 April, 2023 (Shift-I)]**

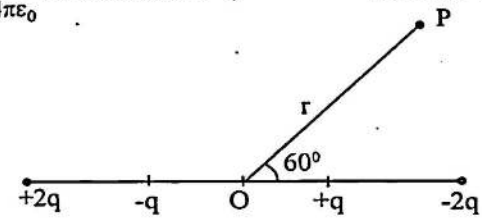
Electric Potential

12. An electric charge $10^{-6}\mu$C is placed at origin (0, 0) m of $X-Y$ co-ordinate system. Two points P and Q are situated at $(\sqrt{3}, \sqrt{3})$ m and $(\sqrt{6}, 0)$ m respectively. The potential difference between the points P and Q will be: **[27 Jan, 2024 (Shift-I)]**

(a) $\sqrt{3}$ V (b) $\sqrt{6}$ V (c) 0 V (d) 3 V

13. The distance between charges +q and –q is $2l$ and between +2 q and -2 q is $4l$. The electrostatic potential at point P at a distance r from centre O is $-\alpha\left[\frac{ql}{r^2}\right]\times 10^9 V$ where the value of α is _____.

$\left(Use \frac{1}{4\pi\varepsilon_0} = 9\times10^9\, Nm^2C^{-2}\right)$ **[31 Jan, 2024 (Shift-II)]**



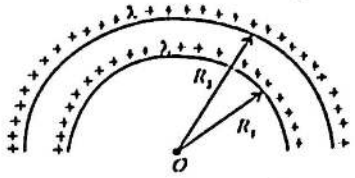
[31 Jan, 2024 (Shift-II)]

14. The electrostatic potential due to an electric dipole at a distance 'r' varies as: **[30 Jan, 2024 (Shift-I)]**

(a) r (b) $\frac{1}{r^2}$ (c) $\frac{1}{r^3}$ (d) $\frac{1}{r}$

15. At the centre of a half ring of radius $R = 10$ cm and linear charge density $4\pi C$ m^{-1}, the potential is $x\pi V$. The value of x is _____. **[09 April, 2024 (Shift-I)]**

16. The electric potential at the centre of two concentric half rings of radii R_1 and R_2, having same linear charge density λ is **[24 Jan, 2023 (Shift-II)]**



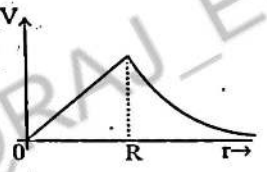
(a) $\frac{2\lambda}{\epsilon_0}$ (b) $\frac{\lambda}{2\epsilon_0}$ (c) $\frac{\lambda}{4\epsilon_0}$ (d) $\frac{\lambda}{\epsilon_0}$

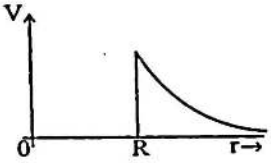
17. Electric potential at a point 'P' due to a point charge of 5×10^{-9} C is 50 V. The distance of 'P' from the point charge is: **[8 April, 2023 (Shift-II)]**

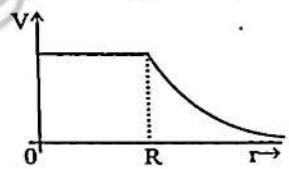
(Assume, $\frac{1}{4\pi\varepsilon_0} = 9\times10^9 Nm^2C^{-2}$)

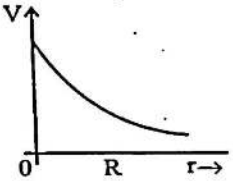
(a) 3 cm (b) 9 cm (c) 90 cm (d) 20..9 cm

18. Which of the following graph correctly represents the variation of electric potential (V) of a charged spherical conductor of radius (R) with radial distance (r) from the centre? **[31 Jan 2023 (Shift-I)]**

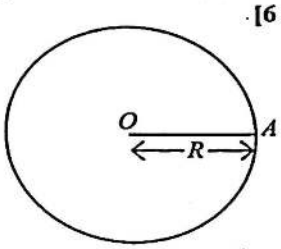
(a) 

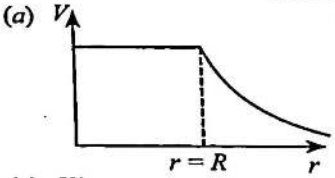
(b) 

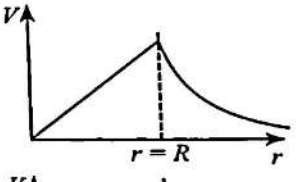
(c) 

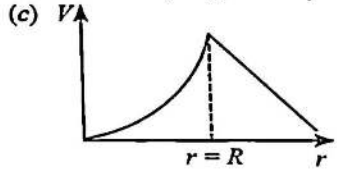
(d) 

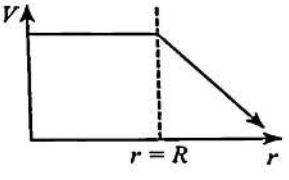
19. For a uniformly charged thin spherical shell, the electric potential (V) radially away from the center (O) of shell can be graphically represented as **[6 April, 2023 (Shift-I)]**



(a) 

(b) 

(c) 

(d) 

@TAKE_OFF_RAJ_EDUNET

20. Three concentric spherical metallic shells X, Y and Z of radius a, b and c respectively $[a < b < c]$ have surface charge densities σ, $-\sigma$ and σ, respectively. The shells X and Z are at same potential. If the radii of X & Y are 2 cm and 3 cm, respectively. The radius of shell Z is ___ cm. **[10 April, 2023 (Shift-I)]**

21. 64 identical drops each charged upto potential of 10mV are combined to form a bigger drop. The potential of the bigger drop will be _____mV. **[12 April, 2023 (Shift-I)]**

22. 27 identical drops are charged at 22V each. They combine to form a bigger drop. The potential of the bigger drop will be _____ V. **[25 June, 2022 (Shift-II)]**

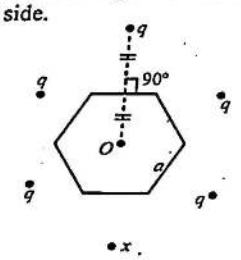
23. Two isolated metallic solid spheres of radii R and $2R$ are charged such that both have same charge density σ. The spheres are then connected by a thin conducting wire. If the new charge density of the bigger sphere is σ'. The ratio $\frac{\sigma'}{\sigma}$ is: **[30 Jan, 2023 (Shift-I)]**

(a) $\frac{9}{4}$ (b) $\frac{4}{3}$ (c) $\frac{5}{3}$ (d) $\frac{5}{6}$

24. Sixty four conducting drops each of radius 0.02 m and each carrying a charge of $5\mu C$ are combined to form a bigger drop. The ratio of surface density of bigger drop to the smaller drop will be **[26 June, 2022 (Shift-II)]**

(a) 1 : 4 (b) 4 : 1 (c) 1 : 8 (d) 8 : 1

25. Six charges are placed around a regular hexagon of side length a as shown in the figure. Five of them have charge q, and the remaining one has charge x. The perpendicular from each charge of the nearest hexagon side passes through the center O of the hexagon and is bisected by the side. **[JEE Adv, 2022]**



Which of the following statements is (are) correct in SI units?

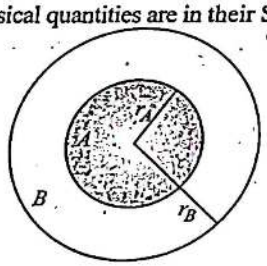
(a) When $x = q$, the magnitude of the electric field at O is zero

(b) When $x = -q$, the magnitude of the electric field at O is $\frac{q}{6\pi\epsilon_0 a^2}$

(c) When $x = 2q$, the potential at O is $\frac{7q}{4\sqrt{3}\pi\epsilon_0 a}$

(d) When $x = -3q$, the potential at O is $-\frac{3q}{4\sqrt{3}\pi\epsilon_0 a}$

26. In the figure, the inner (shaded) region A represents a sphere of radius $r_A = 1$, within which the electrostatic charge density varies with the radial distance r from the center as $\rho_A = kr$, where k is positive. In the spherical shell B of outer radius r_B, the electrostatic charge density varies as $\rho_B = \frac{2k}{r}$. Assume that dimensions are taken care of. All physical quantities are in their SI units. **[JEE Adv, 2022]**



Which of the following statement(s) is(are) correct?

(a) If $r_B = \sqrt{\frac{3}{2}}$, then the electric field is zero everywhere outside B

(b) If $r_B = \frac{3}{2}$, then the electric potential just outside B is $\frac{k}{\epsilon_0}$

(c) If $r_B = 2$, then the total charge of the configuration is $15\pi k$

(d) If $r_B = \frac{5}{2}$, then the magnitude of the electric field just outside B is $\frac{13\pi k}{\epsilon_0}$

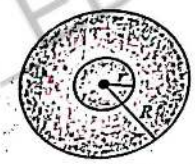
27. The two thin coaxial rings, each of radius 'a' and having charges $+Q$ and $-Q$ respectively are separated by a distance of 's'. The potential difference between the centres of the two rings is: **[26 Aug, 2021 (Shift-II)]**

(a) $\frac{Q}{2\pi\epsilon_0}\left[\frac{1}{a}-\frac{1}{\sqrt{s^2+a^2}}\right]$ (b) $\frac{Q}{4\pi\epsilon_0}\left[\frac{1}{a}-\frac{1}{\sqrt{s^2+a^2}}\right]$

(c) $\frac{Q}{2\pi\epsilon_0}\left[\frac{1}{a}+\frac{1}{\sqrt{s^2+a^2}}\right]$ (d) $\frac{Q}{4\pi\epsilon_0}\left[\frac{1}{a}+\frac{1}{\sqrt{s^2+a^2}}\right]$

28. 512 identical drops of mercury are charged to a potential of 2V each. The drops are joined to form a single drop. The potential of this drop is _____ V. **[25 Feb, 2021 (Shift-I)]**

29. A charge Q is distributed over two concentric conducting thin spherical shells radii r and R $(R > r)$. If the surface charge densities on the two shells are equal, the electric potential at the common center is **[2 Sep, 2020 (Shift-II)]**



(a) $\frac{1}{4\pi\epsilon_0}\frac{(R+r)}{(R^2+r^2)}Q$ (b) $\frac{1}{4\pi\epsilon_0}\frac{(R+2r)Q}{2(R^2+r^2)}$

(c) $\frac{1}{4\pi\epsilon_0}\frac{(R+r)}{2(R^2+r^2)}Q$ (d) $\frac{1}{4\pi\epsilon_0}\frac{(2R+r)}{(R^2+r^2)}Q$

30. Concentric metallic hollow spheres of radii R and $4R$ hold charges Q_1 and Q_2 respectively. Given that surface charge densities of the concentric spheres are equal, the potential difference $V(R) - V(4R)$ is **[3 Sep, 2020 (Shift-II)]**

(a) $\frac{3Q_2}{4\pi\epsilon_0 R}$ (b) $\frac{3Q_1}{16\pi\epsilon_0 R}$ (c) $\frac{Q_2}{4\pi\epsilon_0 R}$ (d) $\frac{3Q_1}{4\pi\epsilon_0 R}$

31. A solid conducting sphere, having a charge Q, is surrounded by an uncharged conducting hollow spherical shell. Let the potential difference between the surface of the solid sphere and that of the outer surface of the hollow shell be V. If the shell is now given a charge of $-4Q$, the new potential difference between the same two surfaces is **[8 April, 2019 (Shift-I)]**

(a) $-2V$ (b) V (c) 2V (d) 4V

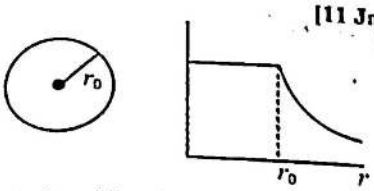
32. A charge Q is distributed over three concentric spherical shell of radii $a, b, c (a < b < c)$ such that their surface charge densities are equal to one another. The total potential at a point at distance r from their common centre, where $r < a$, would be **[10 Jan, 2019 (Shift-I)]**

(a) $\frac{Q(a+b+c)}{4\pi\epsilon_0(a^2+b^2+c^2)}$ (b) $\frac{Q}{4\pi\epsilon_0(a+b+c)}$

(c) $\frac{Q(a^2+b^2+c^2)}{4\pi\epsilon_0(a^3+b^3+c^3)}$ (d) $\frac{Q}{12\pi\epsilon_0}\frac{ab+bc+ca}{abc}$

@FAKE_CBSE_X @RAJ_EDUCATION

33. The given graph shows variation (with distance r from center) of [11 Jnn, 2019 (Shift-I)]



(a) Potential of a uniformly charged spherical shell
(b) Electric field of a uniformly charged sphere
(c) Electric field of uniformly charged spherical shell
(d) Potential of a uniformly charged sphere

34. A thin spherical insulating shell of radius R carries a uniformly distributed charge such that the potential at its surface is V_0. A hole with a small area $\alpha 4\pi R^2$ $(\alpha << 1)$ is made on the shell without affecting the rest of the shell. Which one of the following statements is correct? [JEE Adv, 2019]

(a) The ratio of the potential at the center of the shell to that of the point at 1/2 R from center towards the hole will be $\frac{1-\alpha}{1-2\alpha}$.

(b) The magnitude of electric field at the center of the shell is reduced by $\frac{\alpha V_0}{2R}$

(c) The magnitude of electric field at a point, located on a line passing through the hole and shell's center on a distance $2R$ from the center of the spherical shell will be reduced by $\frac{\alpha V_0}{2R}$

(d) The potential at the center of the shell is reduced by $2\alpha V_0$

35. Considering a group of positive charges, which of the following statements is correct? [31 Jan, 2023 (Shift-II)]

(a) Net potential of the system cannot be zero at a point but net electric field can be zero at that point.

(b) Net potential of the system at a point can be zero but net electric field can't be zero at that point.

(c) Both the net potential and the net field can be zero at a point.

(d) Both the net potential and the net electric field cannot be zero at a point.

36. For a charged spherical ball, electrostatic potential inside the ball varies with r as $V = 2ar^2 + b$.

Here, a and b are constants and r is the distance from the center. The volume charge density inside the ball is $-\lambda a\varepsilon$. The value of λ is _____. [29 Jan, 2023 (Shift-II)]

where ε = permittivity of medium.

37. Consider two charged metallic spheres S_1 and S_2 of radii R_1 and R_2, respectively. The electric fields E_1 (on S_1) and E_2 (on S_2) on their surfaces are such that $E_1/E_2 = R_1/R_2$. Then the ratio V_1(on S_1) / V_2 (on S_2) of the electrostatic potentials on each sphere is [8 Jan, 2020 (Shift-II)]

(a) $\left(\frac{R_1}{R_2}\right)^2$ (b) $\left(\frac{R_1}{R_2}\right)^3$ (c) $\left(\frac{R_2}{R_1}\right)$ (d) $\frac{R_1}{R_2}$

38. Ten charges are placed on the circumference of a circle of radius R with constant angular separation between successive charges. Alternate charges 1, 3, 5, 7, 9 have charge $(+q)$ each, while 2, 4, 6, 8, 10 have charge $(-q)$ each. The potential V and the electric field E at the center of the circle are respectively.(Take $V = 0$ at infinity) [5 Sep, 2020 (Shift-II)]

(a) $V = 0; E = 0$ (b) $V = \frac{10q}{4\pi\varepsilon_0 R}; E = \frac{10q}{4\pi\varepsilon_0 R^2}$

(c) $V = \frac{10q}{4\pi\varepsilon_0 R} = E = 0$ (d) $V = 0; E = \frac{10q}{4\pi\varepsilon_0 R^2}$

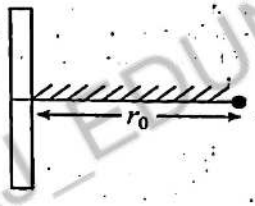
39. A point dipole $\vec{p} = -p_0\hat{x}$ is kept at the origin. The potential and electric field due to this dipole on the y-axis at a distance d are, respectively

(Take $V = 0$ at infinity) [12 April, 2019 (Shift-I)]

(a) $\frac{|\vec{p}|}{4\pi\varepsilon_0 d^2}, \frac{\vec{p}}{4\pi\varepsilon_0 d^3}$ (b) $\frac{|\vec{p}|}{4\pi\varepsilon_0 d^2}, \frac{-\vec{p}}{4\pi\varepsilon_0 d^3}$

(c) $0, \frac{-\vec{p}}{4\pi\varepsilon_0 d^3}$ (d) $0, \frac{\vec{p}}{4\pi\varepsilon_0 d^3}$

40. A positive point charge is released from rest at a distance r_0 from a positive line charge with uniform density. The speed (v) of the point charge, as a function of instantaneous distance r from line charge, is proportional to [8 April, 2019 (Shift-II)]



(a) $v \propto \sqrt{\ln\left(\frac{r}{r_0}\right)}$ (b) $v \propto e^{\frac{r}{r_0}}$

(c) $v \propto \ln\left(\frac{r}{r_0}\right)$ (d) $v \propto \left(\frac{r}{r_0}\right)$

Equipotential Surface, Relation between Field and Potential, Dipole PE

41. Given below are two statements: one is labelled a Assertion (A) and the other is labelled as Reason(R) [27 Jan, 2024 (Shift-II)]

Assertion (A): Work done by electric field on moving a positive charge on an equipotential surface is always zero.

Reason (R): Electric lines of forces are always perpendicular to equipotential surfaces.

In the light of the above statements, choose the most appropriate answer from the options given below:

(a) Both (A) and (R) are correct but (R) is not the correct explanation of (A)

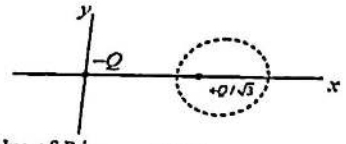
(b) (A) is correct but (R) is not correct

(c) (A) is not correct but (R) is correct

(d) Both (A) and (R) are correct and (R) is the correct explanation of (A)

@FAKE_CBSE_X @RAJ_EDUNET

42. Two point charges $-Q$ and $+Q/\sqrt{3}$ are placed in the xy-plane at the origin (0, 0) and a point (2, 0) respectively, as shown in the figure. This results in an equipotential circle of radius R and potential $V = 0$ in the xy-plane with its center at $(b, 0)$. All lengths are measured in meters. **[JEE Adv, 2021]**

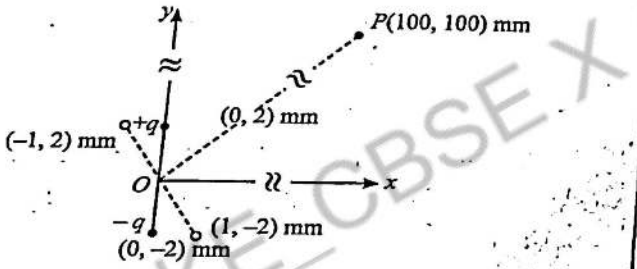


(a) The value of R is ____ meter.
(b) The value of b is ____ meter.

43. If the electric potential at any point (x, y, z) m in space is given by $V = 3x^2$ volt. The electric field at the point (1, 0, 3) m will be: **[29 June, 2022 (Shift-II)]**
(a) 3 Vm^{-1}, directed along positive x-axis.
(b) 3 Vm^{-1}, directed along negative x-axis.
(c) 6 Vm^{-1}, directed along positive x-axis.
(d) 6 Vm^{-1}, directed along negative x-axis.

44. The electric field in a region is given by $\vec{E} = (Ax + B)\hat{i}$, where E is in NC^{-1} and x is in metres. The values of constants are $A = 20$ SI unit and $B = 10$ SI unit. If the potential at $x = 1$ is V_1 and that at $x = -5$ is V_2, then $V_1 - V_2$ is: **[8 April, 2019 (Shift-II)]**
(a) 180 V (b) −520 V (c) 320 V (d) −48 V

45. An electric dipole is formed by two charges $+q$ and $-q$ located in xy-plane at (0, 2) mm and (0, −2) mm, respectively, as shown in the figure. The electric potential at point $P(100, 100)$ mm due to the dipole is V_0. The charges $+q$ and $-q$ are then moved to the points (−1, 2) mm and (1, −2) mm, respectively. What is the value of electric potential at P due to the new dipole ? **[JEE Adv, 2023]**



(a) $V_0/4$ (b) $V_0/2$ (c) $V_0/\sqrt{2}$ (d) $3V_0/4$

46. Two identical electric point dipoles have dipole moments $\overrightarrow{p_1} = p\hat{i}$ and $\overrightarrow{p_2} = -p\hat{i}$ are held on the x axis at distance 'a' from each other. When released, they move along the x-axis with the direction of their dipole moments remaining unchanged. If the mass of each dipole is 'm', their speed when they are infinitely far apart is: **[6 Sep, 2020 (Shift-II)]**

(a) $\frac{p}{a}\sqrt{\frac{1}{\pi\epsilon_0 ma}}$ (b) $\frac{p}{a}\sqrt{\frac{1}{2\pi\epsilon_0 ma}}$
(c) $\frac{p}{a}\sqrt{\frac{2}{\pi\epsilon_0 ma}}$ (d) $\frac{p}{a}\sqrt{\frac{3}{2\pi\epsilon_0 ma}}$

47. An electric field of 1000V/m is applied to an electric dipole at angle of 45°. The value of electric dipole moment is 10^{-29} C.m. What is the potential energy of the electric dipole? **[11 Jan, 2019 (Shift-II)]**
(a) -20×10^{18} J (b) -7×10^{-27} J
(c) -10×10^{-29} J (d) -9×10^{-20} J

48. A point dipole $\vec{p} = -p_0\hat{x}$ is kept at the origin. The potential and electric field due to this dipole on the y-axis at a distance d are, respectively
(Take $V = 0$ at infinity) **[12 April, 2019 (Shift-I)]**
(a) $\frac{|\vec{p}|}{4\pi\epsilon_0 d^2}, \frac{\vec{p}}{4\pi\epsilon_0 d^3}$ (b) $\frac{|\vec{p}|}{4\pi\epsilon_0 d^2}, \frac{-\vec{p}}{4\pi\epsilon_0 d^3}$
(c) $0, \frac{-\vec{p}}{4\pi\epsilon_0 d^3}$ (d) $0, \frac{\vec{p}}{4\pi\epsilon_0 d^3}$

Capacitance, Parallel Plate Capacitor, Dielectric

49. A parallel plate capacitor with plate separation 5 mm is charged up by a battery. It is found that on introducing a dielectric sheet of thickness 2 mm, while keeping the battery connections intact, the capacitor draws 25% more charge from the battery than before. The dielectric constant of the sheet is **[31 Jan, 2024 (Shift-I)]**

50. A parallel plate capacitor of capacitance 12.5 pF is charged by a battery connected between its plates to potential difference of 12.0 V. The battery is now disconnected and a dielectric slab ($\epsilon_r = 6$) is inserted between the plates. The change in its potential energy after inserting the dielectric slab is ____ $\times 10^{-12}$ J. **[04 April, 2024 (Shift-II)]**

51. Given below are two statements: One is labelled as Assertion A and the other is labelled as Reason R.
Assertion (A): Two metallic spheres are charged to the same potential. One of them is hollow and another is solid, and both have the same radii. Solid sphere will have lower charge than the hollow one.
Reason (R): Capacitance of metallic spheres depend on the radii of spheres.
In the light of the above statements, choose the correct answer from the options given below. **[1 Feb, 2023 (Shift-II)]**
(a) A is false but R is true
(b) Both A and R are true and R is the correct explanation of A
(c) A is true but R is false
(d) Both A and R are true but R is not the correct explanation of A

52. A capacitor of capacitance C is charged to a potential V. The flux of the electric field through a closed surface enclosing the positive plate of the capacitor is: **[11 April, 2023 (Shift-II)]**
(a) $\frac{CV}{2\varepsilon_0}$ (b) $\frac{2CV}{\varepsilon_0}$ (c) $\frac{CV}{\varepsilon_0}$ (d) Zero

53. A parallel plate capacitor with air between the plate has a capacitance of 15pF. The separation between the plate becomes twice and the space between them is filled with a medium of dielectric constant 3.5. Then the capacitance becomes $\frac{x}{4}pF$. The value of x is **[24 Jan, 2023 (Shift-II)]**

54. A parallel plate capacitor has plate area 40 cm^2 and plate separation 2 mm. The space between the plates is filled with a dielectric medium of thickness 1 mm and dielectric constant 5. The new capacitance of the system is : **[25 Jan, 2023 (Shift-I)]**
(a) $24\varepsilon_0 F$ (b) $\frac{3}{10}\varepsilon_0 F$ (c) $\frac{10}{3}\varepsilon_0 F$ (d) $10\varepsilon_0 F$

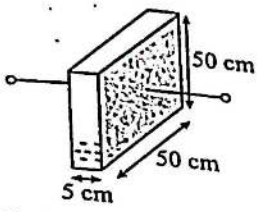
@FIVE_CBSE_X @FIVE_EDUCATION

55. A capacitor has capacitance $5\mu F$ when its parallel plates are separated by air medium of thickness d. A slab of a material of dielectric constant 1.5 having area equal to that of plates but thickness $\frac{d}{2}$ is inserted between the plates. Capacitance of the capacitor in the presence of slab will be _____ μF.

[25 Jan, 2023 (Shift-II)]

56. A container has a base of 50 cm × 5 cm and height 50 cm, as shown in the figure. It has two parallel electrically conducting walls each of area 50 cm × 50 cm. The remaining walls of the container are thin and non-conducting. The container is being filled with a liquid of dielectric constant 3 at a uniform rate of 250 cm^3s^{-1}. What is the value of the capacitance of the container after 10 seconds? [Given: Permittivity of free space $\epsilon_0 = 9 \times 10^{-12}\ C^2N^{-1}m^{-2}$, the effects of the non-conducting walls on the capacitance are negligible]

[JEE Adv, 2023]



(a) 27 pF (b) 63 pF (c) 81 pF (d) 135 pF

57. Two identical thin metal plates has charge q_1 and q_2 respectively such that $q_1 > q_2$. The plates were brought close to each other to from a parallel plate capacitor of capacitance C. The potential difference between them is:

[29 July, 2022 (Shift-II)]

(a) $\frac{(q_1+q_2)}{C}$ (b) $\frac{(q_1-q_2)}{C}$

(c) $\left(\frac{q_1-q_2}{2C}\right)$ (d) $\frac{2(q_1-q_2)}{C}$

58. Capacitance of an isolated conducting sphere of radius R_1 becomes n times when it is enclosed by a concentric conducting sphere of radius R_2 connected to earth. The ratio of their radii $\left(\frac{R_2}{R_1}\right)$ is:

[25 July, 2022 (Shift-II)]

(a) $\frac{n}{n-1}$ (b) $\frac{2n}{2n+1}$ (c) $\frac{n+1}{n}$ (d) $\frac{2n+1}{2n}$

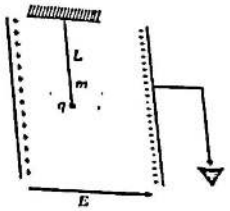
59. A force of 10 N acts on a charged particle placed between two plates of a charged capacitor. If one plate of capacitor is removed, then the force acting on that particle will be. **[27 June, 2022 (Shift-I)]**

(a) 5 N (b) 10 N (c) 20 N (d) Zero

60. An electron with kinetic energy K_1 enters between parallel plates of a capacitor at an angle 'α' with the plates. It leaves the plates at angle 'β' with kinetic energy K_2. Then the ratio of kinetic energies $K_1 : K_2$ will be: **[25 Feb, 2021 (Shift-II)]**

(a) $\frac{\sin^2\beta}{\cos^2\alpha}$ (b) $\frac{\cos\beta}{\cos\alpha}$ (c) $\frac{\cos\beta}{\sin\alpha}$ (d) $\frac{\cos^2\beta}{\cos^2\alpha}$

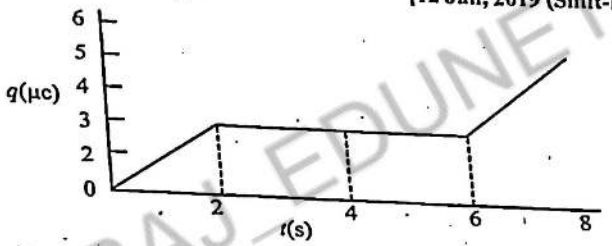
61. A simple pendulum of length L is placed between the plates of a parallel plate capacitor having electric field E, as shown in figure. Its bob has mass m and charge q. The time period of the pendulum is given by **[10 April, 2019 (Shift-II)]**



(a) $2\pi\sqrt{\frac{L}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$ (b) $2\pi\sqrt{\frac{L}{\left(g+\frac{qE}{m}\right)}}$

(c) $2\pi\sqrt{\frac{L}{\left(g-\frac{qE}{m}\right)}}$ (d) $2\pi\sqrt{\frac{L}{\sqrt{g^2-\frac{q^2E^2}{m^2}}}}$

62. The charge on a capacitor plate in a circuit, as a function of time, is shown in the figure: **[12 Jan, 2019 (Shift-II)]**



What is the value of current at $t = 4$ s?

(a) zero (b) 3 μA (c) 2 μA (d) 63..5 μA

63. A parallel plate capacitor is formed by two plates each of area $30\pi cm^2$ separated by 1 mm. A material of dielectric strength $3.6 \times 10^7\ Vm^{-1}$ is filled between the plates. If the maximum charge that can be stored on the capacitor without causing any dielectric breakdown is 7×10^{-6} C, the value of dielectric constant of the material is: **[24 June, 2022 (Shift-I)]**

[Use $\frac{1}{4\pi\epsilon_0} = 9\times10^9\ Nm^2C^{-2}$]

(a) 64...66 (b) 1.75 (c) 2.25 (d) 2.33

64. A parallel plate capacitor with plate area 'A' and distance of separation 'd' is filled with a dielectric. What is the capacity of the capacitor when permittivity of the dielectric varies as:

$\varepsilon(x) = \varepsilon_0 + kx$, for $\left(0 < x \le \frac{d}{2}\right)$

$\varepsilon(x) = \varepsilon_0 + k(d-x)$, for $\left(\frac{d}{2} \le x \le d\right)$

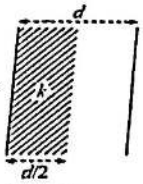
[25 July, 2021 (Shift-I)]

(a) 0 (b) $\frac{kA}{2}\ell n\left(\frac{2\varepsilon_0}{2\varepsilon_0 - kd}\right)$

(c) $\frac{kA}{2\ell n\left(\frac{2\varepsilon_0+kd}{2\varepsilon_0}\right)}$ (d) $\left(\varepsilon_0+\frac{kd}{2}\right)^{2/kA}$

@TAKE CARE YOGRAJ EDUNET

65. In a parallel plate capacitor set up, plate area of capacitor is 2 m² and the plates are separated by 1 m. If the space between the plates are filled with a dielectric material of thickness 0.5 m and area 2 m² (See fig) the capacitance of the set-up will be _____ ϵ_0. (Dielectric constant of the material = 3.2) (Round off to the Nearest Integer) **[16 March, 2021 (Shift-II)]**



66. Voltage rating of a parallel plate capacitor is 500 V. Its dielectric can withstand a maximum electric field of $10^6 \frac{V}{m}$. The plate area is 10^{-4}m². What is the dielectric constant if the capacitance is 15 pF? (given $\epsilon_0 = 8.86 \times 10^{-12}\ C^2/Nm^2$) **[8 April, 2019 (Shift-I)]**

(a) 68...8 (b) 6.2 (c) 4.5 (d) 8.5

67. Parallel plate capacitor of capacitance C has spacing d between two plates having area A. The region between the plates is filled with N dielectric layers, parallel to its plates, each with thickness $\delta = \frac{d}{N}$. The dielectric constant of the m^{th} layer is $K_m = K\left(1+\frac{m}{N}\right)$. For a very large $N(>10^3)$, the capacitance C is $\alpha\left(\frac{K\epsilon_0 a}{d\ell n 2}\right)$. The value of α will be _____. **[JEE Adv, 2019]**

68. If q_f is the free charge on the capacitor plates and q_b is the bound charge on the dielectric slab of dielectric constant k placed between the capacitor plates, then bound charge q_b can be expressed as: **[25 July, 2021 (Shift-II)]**

(a) $q_b = q_f\left(1+\frac{1}{\sqrt{k}}\right)$ (b) $q_b = q_f\left(1-\frac{1}{\sqrt{k}}\right)$

(c) $q_b = q_f\left(1-\frac{1}{k}\right)$ (d) $q_b = q_f\left(1+\frac{1}{k}\right)$

69. A parallel plate capacitor whose capacitance C is 14 pF is charged by a battery to a potential difference $V = 12$ V between its plates. The charging battery is now disconnected and a porcelain plate with $k = 7$ is inserted between the plates, then the plate would oscillate back and forth between the plates with a constant mechanical energy of _____ pJ. (Assume no friction) **[17 March, 2021 (Shift-I)]**

70. A parallel plate capacitor has plate area 100 m² and plate separation of 10m. The space between the plates is filled up to a thickness 5m with material of dielectric constant of 10. The resultant capacitance of the system is 'x' pF.

The value of $\epsilon_0 = 8.85 \times 10^{-12}$ F. m^{-1}

The value of 'x' to the nearest integer is _____.

[18 March, 2021 (Shift-I)]

71. A parallel plate capacitor with plates of area 1 m² each, are at a separation of 0.1 m. If the electric field between the plates is 100 N/C, the magnitude of charge on each plate is: **[12 Jan, 2019 (Shift-II)]**

(a) $74...85 \times 10^{-10}$ C (b) 6.85×10^{-10} C

(c) $75...85 \times 10^{-10}$ C (d) 9.85×10^{-10} C

72. A parallel plate capacitor has 1μF capacitance. One of its two plates is given + 2μC charge and the other plate, +4μC charge. The potential difference developed across the capacitor is: **[8 April, 2019 (Shift-II)]**

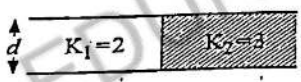
(a) 3V (b) 1V (c) 5V (d) 2V

73. The parallel combination of two air filled parallel plate capacitors of capacitance C and nC is connected to a battery of voltage, V. When the capacitors are fully charged, the battery is removed and after that a dielectric material of dielectric constant K is placed between the two plates of the first capacitor. The new potential difference of the combined system is **[9 April, 2019 (Shift-II)]**

(a) $\frac{(n+1)V}{(K+n)}$ (b) $\frac{V}{K+n}$ (c) V (d) $\frac{nV}{K+n}$

Combination of Capacitors

74. A capacitor of 10 μF capacitance whose plates are separated by 10 mm through air and each plate has area 4 cm² is now filled equally with two dielectric media of $K_1 = 2$, $K_2 = 3$ respectively as shown in figure. If new force between the plates is 8 N. The supply voltage is _____ V. **[06 April, 2024 (Shift-II)]**

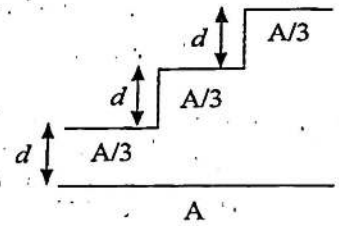


75. A capacitor has air as dielectric medium and two conducting plates of area 12 cm² and they are 0.6 cm apart. When a slab of dielectric having area 12 cm² and 0.6 cm thickness is inserted between the plates, one of the conducting plates has to be moved by 0.2 cm to keep the capacitance same as in previous case. The dielectric constant of the slab is :

(Given $\epsilon_0 = 8.834 \times 10^{-12}$ F/m) **[08 April, 2024 (Shift-II)]**

(a) 1.50 (b) 1.33 (c) 0.66 (d) 1

76. A capacitor is made of a flat plate of area A and a second plate having a stair-like structure as shown in figure. If the area of each stair is $A/3$ and the height is d, the capacitance of the arrangement is: **[09 April, 2024 (Shift-I)]**



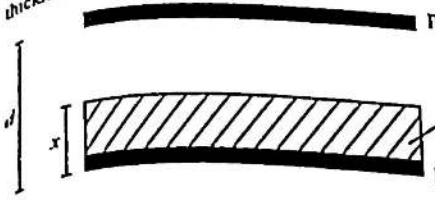
(a) $\frac{11\epsilon_0 A}{18\ d}$ (b) $\frac{13\epsilon_0 A}{17d}$ (c) $\frac{11\epsilon_0 A}{20\ d}$ (d) $\frac{11\epsilon_0 A}{20\ d}$

77. The distance between two plates of a capacitor is d and its capacitance is C_1, when air is the medium between the plates. If a metal sheet of thickness $\frac{2d}{3}$ and of same area as plate is introduced between the plates, the capacitance of the capacitor becomes C_2. The ratio $\frac{C_2}{C_1}$ is: **[10 April, 2023 (Shift-II)]**

(a) 2 : 1 (b) 4 : 1 (c) 3 : 1 (d) 1 : 1

DEAD CBSE X @ TELEGRAM

78. A parallel plate capacitor with plate area A and plate separation d is filled with a dielectric material of dielectric constant $K = 4$. The thickness of the dielectric material is x, where $x < d$.



Let C_1 and C_2 be the capacitance of the system for $x = \frac{1}{3}d$ and $x = \frac{2d}{3}$, respectively. If $C_1 = 2\mu F$ the value of C_2 is ____ μF

[6 April, 2023 (Shift-I)]

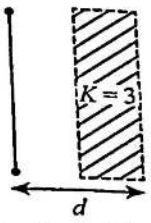
79. Two metallic plates form a parallel plate capacitor. The distance between the plates is 'd'. A metal sheet of thickness $\frac{d}{2}$ and of area equal to area of each plate is introduced between the plates. What will be ratio of the new capacitance to the original capacitance of the capacitor?

[25 June, 2022 (Shift-II)]

(a) 2 : 1 (b) 1 : 2 (c) 1 : 4 (d) 4 : 1

80. A parallel plate capacitor with plate area A and plate separation $d = 2m$ has a capacitance of $4\mu F$. The new capacitance of the system if half of the space between them is filled with a dielectric material of dielectric constant K = 3 (as shown in figure) will be:

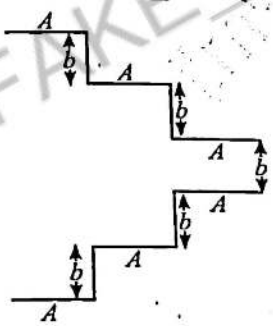
[26 June, 2022 (Shift-II)]



(a) $2\mu F$ (b) $32\mu F$ (c) $6\mu F$ (d) $8\mu F$

81. A parallel plate capacitor is made up of stair like structure with a plate area A of each stair and that is connected with a wire of length b, as shown in the figure. The capacitance of the arrangement is $\frac{x}{15}\frac{\epsilon_0 A}{b}$, the value of x is ____

[27 June, 2022 (Shift-II)]



82. Consider the combination of 2 capacitors C_1 and C_2, with $C_1 > C_2$, when connected in parallel, the equivalent capacitance is $\frac{15}{4}$ times the equivalent capacitance of the same connected in series, Calculate the ratio of capacitors, $\frac{C_2}{C_1}$.

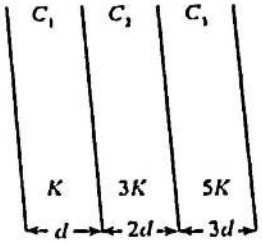
[26 Feb, 2021 (Shift-I)]

(a) $\frac{111}{80}$ (b) $\frac{15}{4}$ (c) $\frac{29}{15}$ (d) $\frac{15}{11}$

83. In the reported figure, a capacitor is formed by placing a compound dielectric between the plates of parallel plate capacitor. The expression for the capacity of the said capacitor will be: (Given area of plate = A)

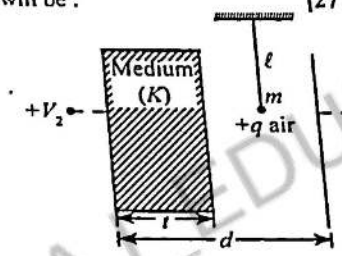
[27 July, 2021 (Shift-I)]

(a) $\frac{15}{34}\frac{K\epsilon_0 A}{d}$ (b) $\frac{15}{6}\frac{K\epsilon_0 A}{d}$ (c) $\frac{25}{6}\frac{K\epsilon_0 A}{d}$ (d) $\frac{9}{6}\frac{K\epsilon_0 A}{d}$



84. A simple pendulum of mass 'm', length 'ℓ' and charge '+ q' suspended in the electric field produced by two conducting parallel plates as shown. The value of deflection of pendulum in equilibrium position will be :

[27 July, 2021 (Shift-II)]



(a) $\tan^{-1}\left[\frac{q}{mg}\times\frac{C_2(V_2-V_1)}{(C_1+C_2)(d-t)}\right]$

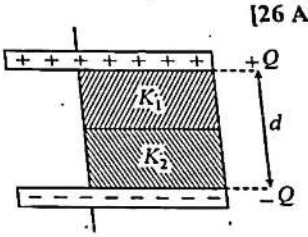
(b) $\tan^{-1}\left[\frac{q}{mg}\times\frac{C_1(V_1+V_2)}{(C_1+C_2)(d-1)}\right]$

(c) $\tan^{-1}\left[\frac{q}{mg}\times\frac{C_1(V_2-V_1)}{(C_1+C_2)(d-t)}\right]$

(d) $\tan^{-1}\left[\frac{q}{mg}\times\frac{C_2(V_1+V_2)}{(C_1+C_2)(d-t)}\right]$

85. A parallel-plate capacitor with plate area A has separation d between the plates. Two dielectric slabs of dielectric constant K_1 and K_2 of same area $\frac{A}{2}$ and thickness $\frac{d}{2}$ are inserted in the space between the plates. The capacitance of the capacitor will be given by:

[26 Aug, 2021 (Shift-II)]

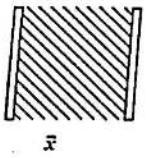


(a) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2}+\frac{K_1+K_2}{K_1K_2}\right)$ (b) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2}+\frac{2(K_1+K_2)}{K_1K_2}\right)$

(c) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2}+\frac{K_1K_2}{K_1+K_2}\right)$ (d) $\frac{\varepsilon_0 A}{d}\left(\frac{1}{2}+\frac{K_1K_2}{2(K_1+K_2)}\right)$

@FAKE_CODEX @RAJEDUNET

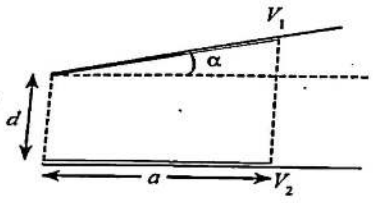
86. A parallel plate capacitor has plates of area A separated by distance 'd' between them. It is filled with a dielectric which has a dielectric constant that varies as $k(x) = k(1 + \alpha x)$ where 'x' is the distance measured from one of the plates.
If $(\alpha d) << 1$, the total capacitance of the system is best given by the expression: **[7 Jan, 2020 (Shift-I)]**



(a) $\frac{AK\varepsilon_0}{d}\left(1+\frac{\alpha d}{2}\right)$ (b) $\frac{A\varepsilon_0 K}{d}\left(1+\frac{\alpha^2 d^2}{2}\right)$

(c) $\frac{AK\varepsilon_0}{d}(1+\alpha d)$ (d) $\frac{A\varepsilon_0 K}{d}\left[1+\left(\frac{\alpha d}{2}\right)^2\right]$

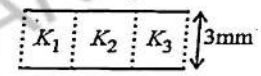
87. A capacitor is made of two square plates each of side 'a' making a very small angle α between them, as shown in figure. The capacitance will be close to:
[8 Jan, 2020 (Shift-II)]



(a) $\frac{\varepsilon_0 a^2}{d}\left(1+\frac{\alpha a}{d}\right)$ (b) $\frac{\varepsilon_0 a^2}{d}\left(1-\frac{\alpha a}{4d}\right)$

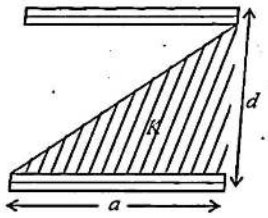
(c) $\frac{\varepsilon_0 a^2}{d}\left(1-\frac{3\alpha a}{2d}\right)$ (d) $\frac{\varepsilon_0 a^2}{d}\left(1-\frac{\alpha a}{2d}\right)$

88. A parallel plate capacitor is of area 6 cm² and a separation 3 mm. The gap is filled with three dielectric materials of equal thickness (see figure) with dielectric constants $K_1 = 10$, $K_2 = 12$ and $K_3 = 14$. The dielectric constant of a material which when fully inserted in above capacitor, gives same capacitance would be **[10 Jan, 2019 (Shift-I)]**



(a) 36 (b) 14 (c) 12 (d) 4

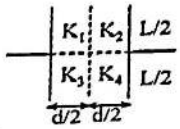
89. A parallel plate capacitor is made of two square plates of side 'a', separated by a distance $d(d << a)$. The lower triangular portion is filled with a dielectric of dielectric constant K, as shown in the figure. Capacitance of this capacitor is **[9 Jan, 2019 (Shift-I)]**



(a) $\frac{K\varepsilon_0 a^2}{d(K-1)}\ln K$ (b) $\frac{K\varepsilon_0 a^2}{d}\ln K$

(c) $\frac{K\varepsilon_0 a^2}{2d(K+1)}$ (d) $\frac{1}{2}\frac{K\varepsilon_0 a^2}{d}$

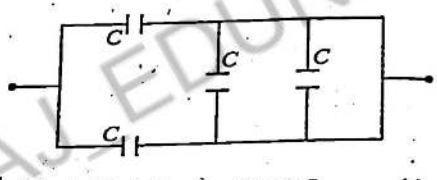
90. A parallel plate capacitor with square plates is filled with four dielectrics of dielectric constants K_1, K_2, K_3, K_4 arranged as shown in the figure. The effective dielectric constant K will be:
[9 Jan, 2019 (Shift-II)]



(a) $K=\frac{(K_1+K_3)(K_2+K_4)}{K_1+K_2+K_3+K_4}$ (b) $K=\frac{(K_1+K_2)(K_3+K_4)}{2(K_1+K_2+K_3+K_4)}$

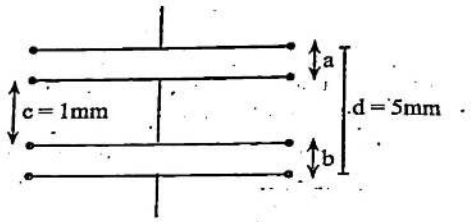
(c) $K=\frac{(K_1+K_2)(K_3+K_4)}{K_1+K_2+K_3+K_4}$ (d) $K=\frac{(K_1+K_4)(K_2+K_3)}{2(K_1+K_2+K_3+K_4)}$

91. The equivalent capacitance of the combination shown is
[10 April, 2023 (Shift-I)]

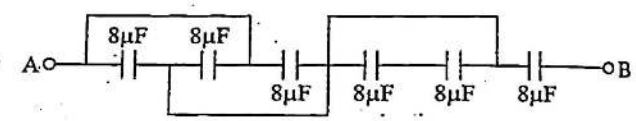


(a) $\frac{C}{2}$ (b) 4 C (c) 2 C (d) $\frac{5}{3}C$

92. As shown in the figure, two parallel plate capacitors having equal plate area of 200 cm² are joined in such a way that $a \neq b$. The equivalent capacitance of the combination is $x\ \varepsilon_0$ F. The value of x is **[06 April, 2023 (Shift-II)]**



93. The equivalent capacitance between points A and B in below shown figure will be _____ μF. **[25 June, 2022 (Shift-I)]**

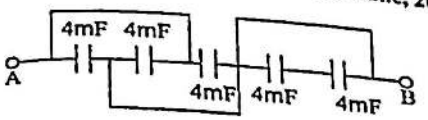


94. Two capacitors, each having capacitance 40μF are connected in series. The space between one of the capacitors is filled with dielectric material of constant K such that the equivalence capacitance of the system became 24μF. The value of K will be:
[28 July, 2022 (Shift-I)]

(a) 95..5 (c) 1.2 (b) 2.5 (d) 3

@FAKEHORSE X @RAJ_EDUNEXT

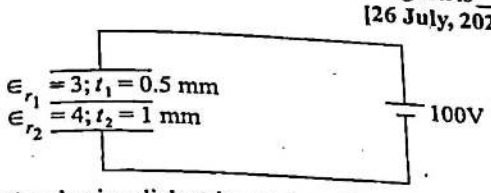
95. The equivalent capacitance between points A and B in below shown figure will be _____ μF. [25 June, 2022 (Shift-I)]



96. A slab of dielectric constant K has the same cross- sectional area as the plates of a parallel plate capacitor and thickness $\frac{3}{4}d$, where d is the separation of the plates. The capacitance of the capacitor when the slab is inserted between the plates will be:
(Given C_0 = capacitance of capacitor with air as medium between plates.) [28 July, 2022 (Shift-II)]

(a) $\frac{4KC_0}{3+K}$ (b) $\frac{3KC_0}{3+K}$ (c) $\frac{3+K}{4KC_0}$ (d) $\frac{K}{4+K}$

97. A composite parallel plate capacitor is made up of two different dielectric materials with different thickness (t_1 and t_2) as shown in figure. The two different dielectric materials are separated by a conducting foil F. The voltage of the conducting foil is _____ V. [26 July, 2022 (Shift-I)]



98. A medium having dielectric constant $K>1$ fills the space between the plates of a parallel plate capacitor. The plates have large area, and the distance between them is d. The capacitor is connected to a battery of voltage V. as shown in Figure (a). Now, both the plates are moved by a distance of $d/2$ from their original positions, as shown in figure (b).

In the process of going from the configuration depicted in Figure (a) to that in Figure (b), which of the following statement(s) is(are) correct? [JEE Adv, 2022]

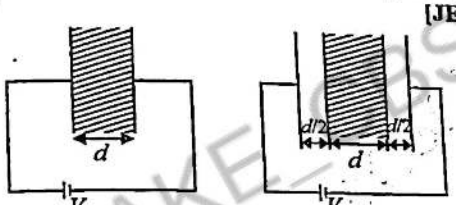


Figure (a) Figure (b)

(a) The electric field inside the dielectric material is reduced by a factor of $2K$

(b) The capacitance is decreased by a factor of $\frac{1}{K+1}$.

(c) The voltage between the capacitor plates is increased by a factor of $(K+1)$

(d) The work done in the process does not depend on the presence of the dielectric material

99. For changing the capacitance of a given parallel plate capacitor, a dielectric material of dielectric constant K is used, which has the same area as the plates of the capacitor. The thickness of the dielectric slab is $\frac{3}{4}d$, where 'd' is the separation between the plates of parallel plate capacitor. The new capacitance (C') in terms of original capacitance (C_0) is given by the following relation: [16 March, 2021 (Shift-I)]

(a) $C' = \frac{4+K}{3}C_0$ (b) $C' = \frac{3+K}{4K}C_0$

(c) $C' = \frac{4}{3+K}C_0$ (d) $C' = \frac{4K}{K+3}C_0$

100. Two capacitors of capacities $2C$ and C are joined in parallel and charge up to potential V. The battery is removed and the capacitor of capacity C is filled completely with a medium of dielectric constant K. The potential difference across the capacitors will now be: [27 July, 2021 (Shift-I)]

(a) $\frac{3V}{K}$ (b) $\frac{V}{K}$ (c) $\frac{V}{K+2}$ (d) $\frac{3V}{K+2}$

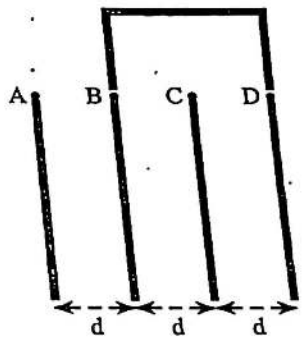
101. Two equal capacitors are first connected in series and then in parallel. The ratio of the equivalent capacities in the two cases will be: [24 Feb, 2021 (Shift-I)]

(a) 4:1 (b) 1:2 (c) 1:4 (d) 2:1

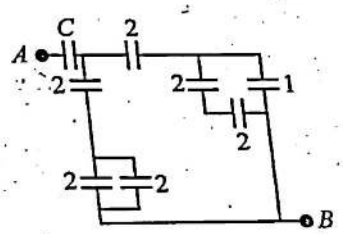
102. Consider the combination of 2 capacitors C_1 and C_2, with $C_1 > C_2$, when connected in parallel, the equivalent capacitance is $\frac{15}{4}$ times the equivalent capacitance of the same connected in series, Calculate the ratio of capacitors, $\frac{C_2}{C_1}$. [26 Feb, 2021 (Shift-I)]

(a) $\frac{111}{80}$ (b) $\frac{15}{4}$ (c) $\frac{29}{15}$ (d) $\frac{15}{11}$

103. Four identical rectangular plates with length, $\ell = 2$ and breadth, $b = \frac{3}{2}cm$ are arranged as shown in figure. The equivalent capacitance between A and C is $\frac{x\varepsilon_0}{d}$. The value of x is _____
(Round off to the nearest integer) [17 March, 2021 (Shift-I)]



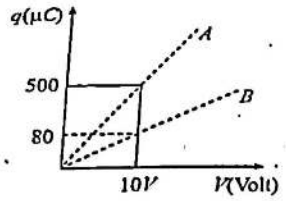
104. In the circuit shown, find C if the effective capacitance of the whole circuit is to be 0.5 μF. All values in the circuit are in μF. [12 Jan, 2019 (Shift-II)]



(a) $\frac{7}{11}\mu F$ (b) $4\mu F$ (c) $\frac{6}{5}\mu F$ (d) $\frac{7}{10}\mu F$

@EAKE_CASE @RAJ_EDUNET

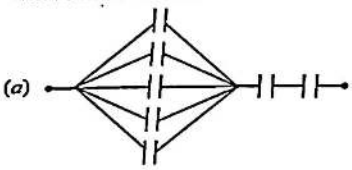
105. Figure shows charge (q) versus voltage (V) graph for series and parallel combination of two given capacitors. The capacitances are
[10 April, 2019 (Shift-I)]



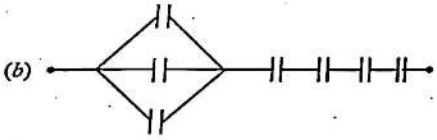
(a) 40μF and 10μF (b) 20μF and 30μF
(c) 60μF and 40μF (d) 50μF and 30μF

106. Seven capacitors, each of the capacitance $2\mu F$, are to be connected in a configuration to obtain an effective capacitance of $\left(\frac{6}{13}\right)\mu F$. Which of the combinations, shown in figures below, will achieve the desired value? **[11 Jan, 2019 (Shift-II)]**

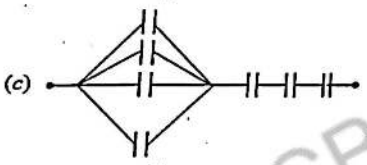
(a)



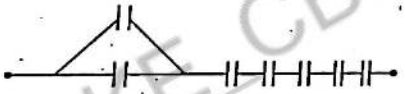
(b)



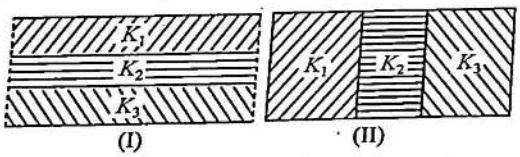
(c)



(d)



107. Two identical parallel plate capacitors, of capacitance C each, have plates of area A, separated by a distance d. The space between the plates of the two capacitors, is filled with three dielectrics, of equal thickness and dielectric constants K_1, K_2 and K_3. The first capacitor is filled as shown in fig. I, and the second one is filled as shown in fig II.
If these two modified capacitors are charged by the same potential V, the ratio of the energy stored in the two, would be (E_1 refers to capacitor (I) and E_2 to capacitor (II)) **[12 April, 2019 (Shift-I)]**



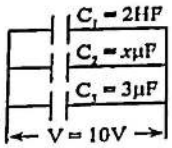
(a) $\frac{E_1}{E_2}=\frac{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}{K_1K_2K_3}$

(b) $\frac{E_1}{E_2}=\frac{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}{9K_1K_2K_3}$

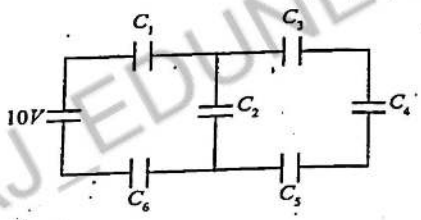
(c) $\frac{E_1}{E_2}=\frac{9K_1K_2K_3}{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}$

(d) $\frac{E_1}{E_2}=\frac{K_1K_2K_3}{(K_1+K_2+K_3)(K_2K_3+K_3K_1+K_1K_2)}$

108. In the given figure the total charge stored in the combination of capacitors is 100 μC. The value of 'x' is_____.
[15 April, 2023 (Shift-I)]



109. In the given circuit,
$C_1 = 2\ \mu F$, $C_2 = 0.2\ \mu F$, $C_3 = 2\ \mu F$, $C_4 = 4\ \mu F$, $C_5 = 2\ \mu F$, $C_6 = 2\ \mu F$, the charge stored on capacitor C_4 is _____ μC.
[11 April, 2023 (Shift-II)]

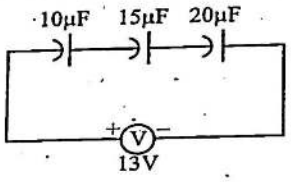


110. The total charge on the system of capacitors $C_1 = 1\ \mu F$, $C_2 = 2\mu F$, $C_3 = 4\mu F$ and $C_4 = 3\mu F$ connected in parallel is:
(Assume a battery of 20V is connected to the combination)
[26 July, 2022 (Shift-I)]

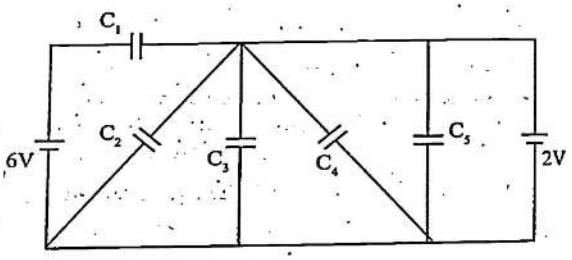
(a) 200μC (b) 200 C (c) 10μC (d) 10 C

111. The charge on capacitor of capacitance $15\mu F$ in the figure given below is:
[26 June, 2022 (Shift-II)]

(a) 60μC (b) 130μC (c) 260μC (d) 585μC

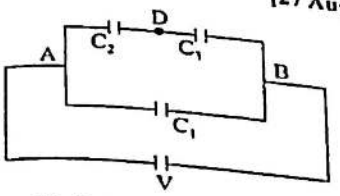


112. In the following circuit $C_1 = 12\ \mu F$, $C_2 = C_3 = 4\ \mu F$ and $C_4 = C_5 = 2\ \mu F$. The charge stored in C_3 is _____ μC.
[JEE Adv, 2022]



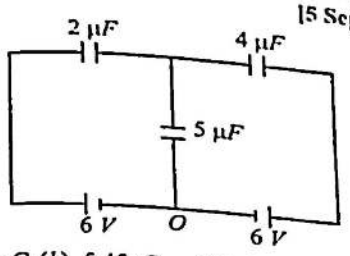
@NEET_CBSE X @RAJ_EDUNET

113. Three capacitors $C_1 = 2\mu F$, $C_2 = 6\mu F$ and $C_3 = 12\mu F$ are connected as shown in figure. Find the ratio of the charges on capacitors C_1, C_2 and C_3 respectively: [27 Aug, 2021 (Shift-II)]



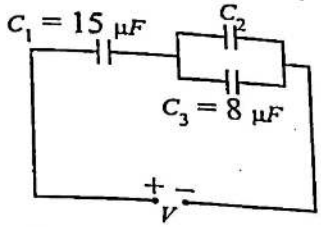
(a) 2:1:1 (b) 3:4:4 (c) 2:3:3 (d) 1:2:2

114. In the circuit shown, charge on the $5\mu F$ capacitor is: [5 Sep, 2020 (Shift-II)]



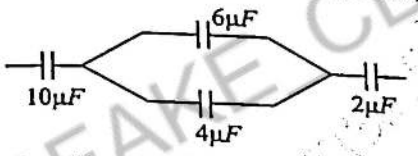
(a) 115..36μC (b) 5.45μC (c) 10.90μC (d) 18.00μC

115. In the circuit shown in the figure, the total charge is 750 μC and the voltage across capacitor C_2 is 20 V. Then the charge on capacitor C_2 is [3 Sep, 2020 (Shift-I)]



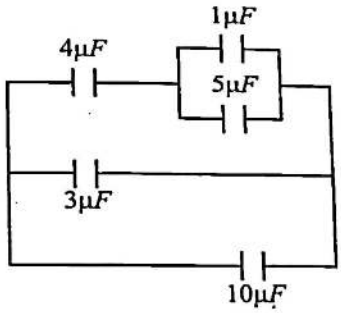
(a) 160 μC (b) 650 μC (c) 590 μC (d) 450 μC

116. In the figure shown below, the charge on the left plate of the 10 μF capacitor is –30 μC. The charge on the right plate of the 6 μF capacitor is [11 Jan, 2019 (Shift-I)]



(a) +18 μC (b) –12 μC (c) +12 μC (d) –18 μC

117. In the given circuit, the charge on $4\mu F$ capacitor will be : [12 April, 2019 (Shift-II)]



(a) 119..4μC (b) 24μC (c) 9.6μC (d) 5.4μC

Energy Stored in Capacitors & sharing of charge between capacitors

118. A capacitor of capacitance C and potential V has energy E. It is connected to another capacitor of capacitance $2C$ and potential $2V$. Then the loss of energy is $\frac{x}{3}E$, where x is _____. [30 Jan, 2024 (Shift-I)]

119. Two identical capacitors have same capacitance C. One of them is charged to the potential V and other to the potential $2V$. The negative ends of both are connected together. When the positive ends are also joined together, the decrease in energy of the combined system is: [1 Feb, 2024 (Shift-I)]

(a) $\frac{1}{4}CV^2$ (b) $2CV^2$ (c) $\frac{1}{2}CV^2$ (d) $\frac{3}{4}CV^2$

120. Three capacitors of capacitances 25 μF, 30 μF and 45 μF are connected in parallel to a supply of 100 V. Energy stored in the above combination is E. When these capacitors are connected in series to the same supply, the stored energy is $\frac{9}{x}E$. The value of x is ..... [05 April, 2024 (Shift-I)]

121. Two charged conducting spheres of radii a and b are connected to each other by a conducting wire. The ratio of charges of the two spheres respectively is: [08 April, 2024 (Shift-I)]

(a) $\sqrt{ab}$ (b) ab (c) a/b (d) b/a

122. Two parallel plate capacitors C_1 and C_2 each having capacitance of 10μF are individually charged by a 100 V D.C. source. Capacitor C_1 is kept connected to the source and a dielectric slab is inserted between it plates. Capacitor C_2 is disconnected from the source and then a dielectric slab is inserted in it. Afterwards the capacitor C_1 is also disconnected from the source and the two capacitors are finally connected in parallel combination. The common potential of the combination will be _____ V. (Assuming Dielectric constant = 10) [31 Jan, 2023 (Shift-II)]

123. A parallel plate capacitor of capacitance 200 μF is connected to a battery of 200 V. A dielectric slab of dielectric constant 2 is now inserted into the space between plates of capacitor while the battery remain connected. The change in the electrostatic energy in the capacitor will be_____J. [31 Aug, 2021 (Shift-II)]

124. A capacitor of capacitance 50 pF is charged by 100 V source. It is then connected to another uncharged identical capacitor. Electrostatic energy loss in the process is _____nJ. [27 June, 2022 (Shift-I)]

125. Effective capacitance of parallel combination of two capacitors C_1 and C_2 is 10 μF. When these capacitor are individually connected to a voltage source of 1 V, the energy stored in the capacitor C_2 is 4 times that of C_1. If these capacitors are connected in series, their effective capacitance will be [8 Jan, 2020 (Shift-I)]

(a) 126...2 μF (b) 8.4 μF (c) 1.6 μF (d) 4.2 μF

126. A parallel plate capacitor of capacitance 2 F is charged to a potential V. The energy stored in the capacitor is E_1. The capacitor is now connected to another uncharged identical capacitor in parallel combination. The energy stored in the combination is E_2. The ratio E_2/E_1 is: [11 April, 2023 (Shift-I)]

(a) 2 : 1 (b) 1 : 2 (c) 1 : 4 (d) 2 : 3

@FAKE_CBSE_X_GRAL_EDUNE

127. A capacitor of capacitance $900\mu F$ is charged by a 100V battery. The capacitor is disconnected from the battery and connected to another uncharged identical capacitor such that one plate of uncharged capacitor connected to positive plate and another plate of uncharged capacitor connected to negative plate of the charged capacitor. The loss of energy in this process is measured as $x\times10^{-2}$ J. The value of x is _____. **[30 Jan, 2023 (Shift-I)]**

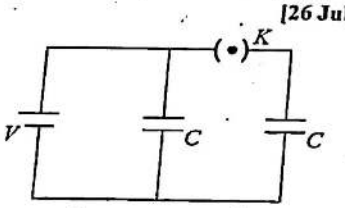
128. A $600\,pF$ capacitor is charged by $200\,V$ supply. It is then disconnected from the supply and is connected to another uncharged $600\,pF$ capacitor. Electrostatic energy lost in the process is _____μJ.
[8 April, 2023 (Shift-II)]

129. A capacitor of capacitance 50 pF is charged by 100 V source. It is then connected to another uncharged identical capacitor. Electrostatic energy loss in the process is _____nJ.
[27 June, 2022 (Shift-I)]

130. If the charge on a capacitor is increased by 2C, the energy stored in it increases by 44%. The original charge on the capacitor is (in C)
[24 June, 2022 (Shift-II)]

(a) 10 (b) 20 (c) 30 (d) 40

131. A source of potential difference V is connected to the combination of two identical capacitors as shown in the figure. When key 'K' is closed, the total energy stored across the combination is E_1. Now key 'K' is opened and dielectric of dielectric constant 5 is introduced between the plates of the capacitors. The total energy stored across the combination is now E_2. The ratio E_1/E_2 will be:
[26 July, 2022 (Shift-II)]



(a) $\frac{1}{10}$ (b) $\frac{2}{5}$ (c) $\frac{5}{13}$ (b) $\frac{5}{26}$

132. A parallel plate capacitor filled with a medium of dielectric constant 10, is connected across a battery and is charged. The dielectric slab is replaced by another slab of dielectric constant 15. Then the energy of capacitor will:
[29 June, 2022 (Shift-I)]

(a) Increase by 50% (b) Increase by 25%
(c) Decrease by 15% (d) Increases by 33%

133. A parallel plate capacitor with width 4 cm, length 8cm and separation between the plates of 4 mm is connected to a battery of 20 V. A dielectric slab of dielectric constant 5 having length 1 cm, width 4 cm and thickness 4 mm is inserted between the plates of parallel plate capacitor. The electrostatic energy of this system will be _____ ϵ_0 J.
(Where ϵ_0 is the permittivity of free space)
[27 July, 2022 (Shift-II)]

134. Two parallel plate capacitors of capacity C and 3C are connected in parallel combination and charged to a potential difference 18 V. The battery is then disconnected and the space between the plates of the capacitor of capacity C is completely filled with a material of dielectric constant 9. The final potential difference across the combination of capacitors will be _____V.
[25 July, 2022 (Shift-II)]

135. A capacitor C is fully charged with voltage V_0. After disconnecting the voltage source, it is connected in parallel with another uncharged capacitor of capacitance. $\frac{C}{2}$. The energy loss in the process after the charge is distributed between the two capacitor is:
[4 Sep, 2020 (Shift-II)]

(a) $\frac{1}{6}CV_0^2$ (b) $\frac{1}{2}CV_0^2$ (c) $\frac{1}{4}CV_0^2$ (d) $\frac{1}{3}CV_0^2$

136. A parallel plate capacitor has plate of length 'ℓ', width 'w' and separation of plates is 'd'. It is connected to a battery of emf V. A dielectric slap of the same thickness 'd' and of dielectric constant $K = 4$ is being, inserted between the plates of the capacitor. At what length of the slab inside plates, will be energy stored in the capacitor be two times the initial energy stored? **[5 Sep, 2020 (Shift-II)]**

(a) $2\ell/3$ (b) $\ell/2$ (c) $\ell/4$ (d) $\ell/3$

137. Two capacitors of capacitances C and $2C$ are charged to potential differences V and $2\,V$, respectively. These are then connected in parallel in such a manner that the positive terminal of one is connected to the negative terminal of the other. The final energy of this configuration is: **[5 Sep, 2020 (Shift-I)]**

(a) $\frac{3}{2}CV^2$ (b) $\frac{9}{2}CV^2$ (c) $\frac{25}{6}CV^2$ (d) zero

138. Two capacitors with capacitance values $C_1 = 2000 \pm 10$ pF and $C_2 = 3000 \pm 15$ pF are connected in series. The voltage applied across this combination is $V = 5.00 \pm 0.02$ V. The percentage error in the calculation of the energy stored in this combination of capacitors is _____. **[JEE Adv, 2020]**

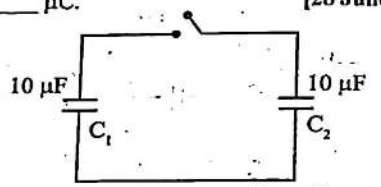
139. A parallel plate capacitor having capacitance 12 pF is charged by a battery to a potential difference of 10 V between its plates. The charging battery is now disconnected and a porcelain slab of dielectric constant 6.5 is slipped between the plates. The work done by the capacitor on the slab is: **[10 Jan, 2019 (Shift-II)]**

(a) 692 pJ (b) 508 pJ (c) 560 pJ (d) 600 pJ

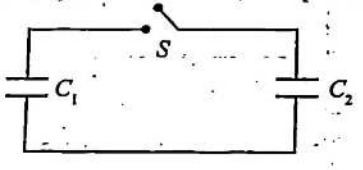
140. A capacitor with capacitance 5 μF is charged to 5 μC. If the plates are pulled apart to reduce the capacitance to 2 μF, how much work is done? **[9 April, 2019 (Shift-I)]**

(a) 3.75×10^{-6} J (b) 2.55×10^{-6} J
(c) 142.25×10^{-6} J (d) 2.16×10^{-6} J

141. A capacitor C_1 of capacitance 5 μF is charged to a potential of 30 V using a battery. The battery is then removed and the charged capacitor is connected to an uncharged capacitor C_2 of capacitance 10 μF as shown in figure. When the swich is closed charge flows between the capacitors. At equilibrium, the charge on the capacitor C_2 is _____ μC. **[28 June, 2022 (Shift-II)]**



142. Two capacitors having C_1 and C_2 respectively are connected as shown in figure. Initially, capacitor C_1 is charged to a potential difference V volt by a battery. The battery is then removed and the charged capacitor C_1 is now connected to uncharged capacitor C_2 by closing the switch S. The amount of charge on the capacitor C_2, after equilibrium, is: **[26 June, 2022 (Shift-I)]**

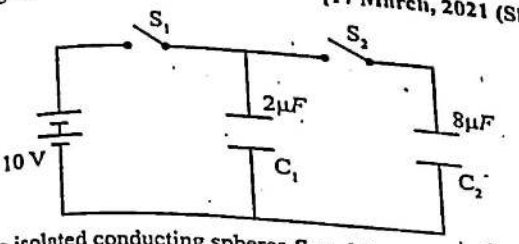


(a) $\frac{C_1C_2}{(C_1+C_2)}V$ (b) $\frac{(C_1+C_2)}{C_1C_2}V$ (c) $(C_1+C_2)V$ (d) $(C_1-C_2)V$

© CBSE @RVC

143. A 10 mF capacitor is fully charged to a potential difference of 50 V. After removing the source voltage, it is connected to an uncharged capacitor in parallel. Now potential difference across them becomes 20 V. The capacitance of the second capacitor is:
(a) 15 μF (b) 20 μF (c) 10 μF (d) 30 μF

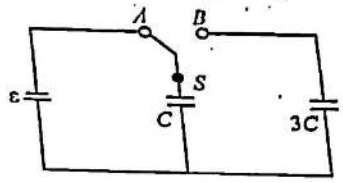
144. A $2\mu F$ capacitor C_1 is first charged to a potential difference of 10 V using a battery. Then the battery is removed and the capacitor is connected to an uncharged capacitor C_2 of $8\mu F$. The charge in C_2 on equilibrium condition is _____ μC. (Round off to the Nearest integer) [17 March, 2021 (Shift-II)]



145. Two isolated conducting spheres S_1 and S_2 of radius $\frac{2}{3}R$ and $\frac{1}{3}R$ have 12 μC and −3 μC charges, respectively, and are at a large distance from each other. They are now connected by a conducting wire. A long time after this is done the charges on S_1 and S_2 are respectively: [3 Sep, 2020 (Shift-I)]
(a) +4.5 μC and −4.5 μC (b) 148..5 μC on both
(c) 6 μC and 3 μC (d) 3 μC and 6 μC

146. A 5μF capacitor is charged fully by a 220 V supply. It is then disconnected form the supply and is connected in series to another uncharged 2.5 μF capacitor. If the energy change during the charge redistribution is $\frac{X}{100}$ J then value of X to the nearest integer is: [2 Sep, 2020 (Shift-I)]

147. In the figure shown, after the switch 'S' is turned from position 'A' to position 'B', the energy dissipated in the circuit in terms of capacitance 'C' and total charge 'Q' is [12 Jan, 2019 (Shift-I)]



(a) $\frac{3Q^2}{8C}$ (b) $\frac{1Q^2}{8C}$ (c) $\frac{5Q^2}{8C}$ (d) $\frac{3Q^2}{4C}$

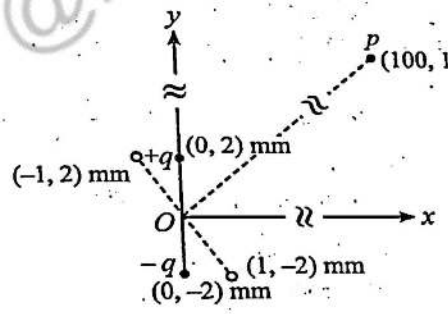
JEE-Advanced

Electrostatic Potential and Potential Energy, Electric Dipole

Single Correct

1. An electric dipole is formed by two charges $+q$ and $-q$ located in x–y - plane at (0, 2) mm and (0, –2) mm, respectively, as shown in the figure. The electric potential at point P(100, 100) mm due to the dipole is V_0. The charges $+q$ and $-q$ are then moved to the points (–1, 2) mm and (1, –2) mm, respectively. What is the value of electric potential at P due to the new dipole?

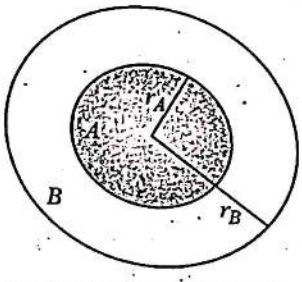
C-12.26 W-31.3 UA-56.44 (JEE Adv. 2023)



(a) $V_0/4$ (b) $V_0/2$
(c) $V_0/\sqrt{2}$ (d) $3V_0/4$

2. In the figure, the inner (shaded) region A represents a sphere of radius r_A=1, within which the electrostatic charge density varies with the radial distance r from the center as $\rho_A = kr$, where k is positive. In the spherical shell B of outer radius r_B, the electrostatic charge density varies as $\rho_B = \frac{2k}{r}$. Assume that dimensions are taken care of. All physical quantities are in their SI units.

C-10.43 W-27.25 UA-62.32 (JEE Adv. 2022)



Which of the following statement(s) is/are correct?

(a) If $r_B = \sqrt{\frac{3}{2}}$, then the electric field is zero everywhere outside B

(b) If $r_B = \frac{3}{2}$, then the electric potential just outside B is $\frac{k}{\epsilon_0}$

(c) If $r_B = 2$, then the total charge of the configuration is $15\pi k$

(d) If $r_B = \frac{5}{2}$, then the magnitude of the electric field just outside B is $\frac{13\pi k}{\epsilon_0}$

@FAKE_CBSE_X_CBAJ_EDUNET

3. A thin spherical insulating shell of radius R carries a uniformly distributed charge such that the potential at its surface is V_0. A hole with a small area $\alpha 4\pi R^2$ ($\alpha << 1$) is made on the shell without affecting the rest of the shell. Which one of the following statements is correct? **C-14 W-31 UA-56 (JEE Adv. 2019)**

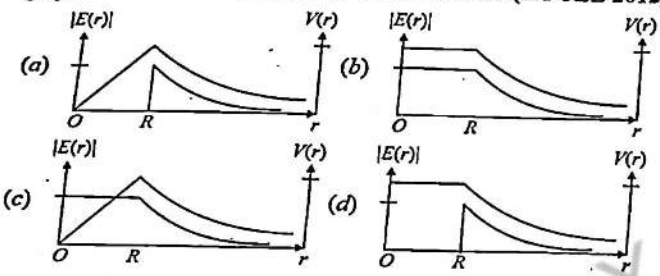
(a) The ratio of the potential at the center of the shell to that of the point at $1/2R$ from center towards the hole will be $\frac{1-\alpha}{1-2\alpha}$

(b) The magnitude of electric field at the center of the shell is reduced by $\frac{\alpha V_0}{2R}$

(c) The magnitude of electric field at a point, located on a line passing through the hole and shell's center on a distance $2R$ from the center of the spherical shell will be reduced by $\frac{\alpha V_0}{2R}$

(d) The potential at the center of the shell is reduced by $2\alpha V_0$

4. Consider a thin spherical shell of radius R with its center at the origin, carrying uniform positive surface charge density. The variation of the magnitude of the electric field $|E(r)|$ and the electric potential $V(r)$ with the distance r from the center, is best represented by which graph? **C-31.05 W-40.35 UA-28.6 (IIT-JEE 2012)**



5. Positive and negative point charges of equal magnitude are kept at $(0, 0, a/2)$ and $(0, 0, -a/2)$, respectively. The work done by the electric field when another positive point charge is moved from $(-a, 0, 0)$ to $(0, a, 0)$ is **(IIT-JEE 2007)**

(a) positive

(b) negative

(c) zero

(d) depends on the path connecting the initial and final positions

6. A long, hollow conducting cylinder is kept co-axially inside another long, hollow conducting cylinder of larger radius. Both the cylinders are initially electrically neutral. **(IIT-JEE 2007)**

(a) A potential difference appears between the two cylinders when a charge density is given to the inner cylinder.

(b) A potential difference appears between the two cylinders when a charge density is given to the outer cylinder.

(c) No potential difference appears between the two cylinders when a uniform line charge is kept along the axis of the cylinders.

(d) No potential difference appears between the two cylinders when same charge density is given to both the cylinders.

7. A charge $+q$ is fixed at each of the points $x = x_0, x = 3x_0, x = 5x_0 \ldots \infty$ on the x-axis and a charge $-q$ is fixed at each of the points $x = 2x_0, x = 4x_0, x = 6x_0 \ldots, \infty$, Here, x_0 is a positive constant. Take the electric potential at a point due to a charge Q at a distance r from it to be $Q/4\pi\varepsilon_0 r$. Then the potential at the origin due to the above system of charges is **(IIT-JEE 1998)**

(a) zero (b) $\frac{q}{8\pi\varepsilon_0 x_0 \ln 2}$

(c) infinite (d) $\frac{q \ln(2)}{4\pi\varepsilon_0 x_0}$

8. A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. The potential at the centre of the sphere is **(IIT-JEE 1983)**

(a) zero

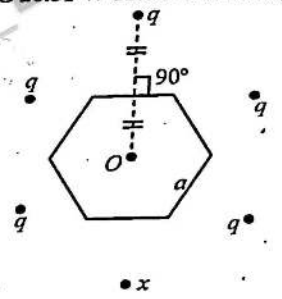
(b) 10 V

(c) same as at a point 5 cm away from the surface

(d) same as at a point 25 cm away from the surface

Multiple Correct

9. Six charges are placed around a regular hexagon of side length a as shown in the figure. Five of them have charge q, and the remaining one has charge x. The perpendicular from each charge of the nearest hexagon side passes through the center O of the hexagon and is bisected by the side. **C 20.51 W 12.82 UA 27.53 (JEE Adv. 2022)**



Which of the following statements is/are correct in SI units?

(a) When $x = q$, the magnitude of the electric field at O is zero

(b) When $x = -q$, the magnitude of the electric field at O is $\frac{q}{6\pi\epsilon_0 a^2}$

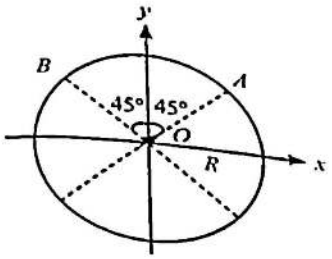
(c) When $x = 2q$, the potential at O is $\frac{7q}{4\sqrt{3}\pi\epsilon_0 a}$

(d) When $x = -3q$, the potential at O is $-\frac{3q}{4\sqrt{3}\pi\epsilon_0 a}$

10. An electric dipole with dipole moment $\frac{p_0}{\sqrt{2}}(\hat{i}+\hat{j})$ is held fixed at the origin O in the presence of an uniform electric field of magnitude E_0. If the potential is constant on a circle of radius R centered at the origin as shown in figure, then the correct statement(s) is/are: (ϵ_0 is permittivity of free space. $R >>$ dipole size)

C-3.04 W-50.3 UA-38.12 PC-8.53 (JEE Adv. 2019)

@FAKE_CBSE_EX @RAJ_TOMAR



(a) $R=\left(\frac{p_0}{4\pi\epsilon_0 E_0}\right)^{1/3}$

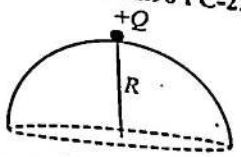
(b) Total electric field at point is $\vec{E}_A=\sqrt{2}E_0(i+j)$

(c) Total electric field at point B is $\vec{E}_B=0$

(d) The magnitude of total electric field on any two points of the circle will be same

11. A point charge $+Q$ is placed just outside an imaginary hemispherical surface of radius R as shown in the figure. Which of the following statements is/are correct?

C-8.24 W-35.9 UA-32.96 PC-22.9 (JEE Adv. 2017)



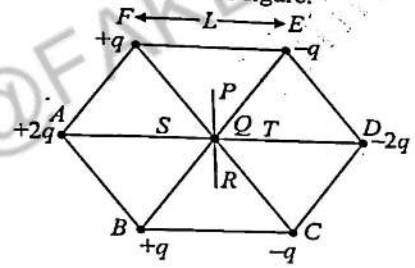
(a) The electric flux passing through the curved surface of the hemisphere is $-\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$

(b) The component of the electric field normal to the flat surface is constant over the surface

(c) Total flux through the curved and the flat surfaces is $\frac{Q}{\varepsilon_0}$

(d) The circumference of the flat surface is an equipotential

12. Six point charges are kept at the vertices of a regular hexagon of side L and centre O as shown in the figure.



Given that

$K=\frac{1}{4\pi\varepsilon_0}\frac{q}{L^2}$, which of the following statements(s) is/are correct

C-9.99 W-87.25 UA-2.75 (IIT-JEE 2012)

(a) The electric field at O is $6K$ along OD

(b) The potential at O is zero

(c) The potential at all points on the line PR is same

(d) The potential at all points on the line ST is same

13. Which of the following statement(s) is/are correct?

(IIT-JEE 2011)

(a) If the electric field due to a point charge varies as $r^{-2.5}$ instead of r^{-2}, then the Gauss's law will still be valid

(b) The Gauss's law can be used to calculate the field distribution around an electric dipole

(c) If the electric field between two point charges is zero somewhere, then the sign of the two charges is the same

(d) The work done by the external force in moving a unit positive charge from point A at potential V_A to point B at potential V_B is (V_B-V_A)

14. Which of the following statement(s) is/are correct?

(IIT-JEE 2011)

(a) If the electric field due to a point charge varies as $r^{-2.5}$ instead of r^{-2}, then the Gauss's law will still be valid

(b) The Gauss's law can be used to calculate the field distribution around an electric dipole

(c) If the electric field between two point charges is zero somewhere, then the sign of the two charges is the same

(d) The work done by the external force in moving a unit positive charge from point A at potential V_A to point B at potential V_B is (V_B-V_A)

15. A spherical metal shell A of radius R_A and a solid metal sphere B of radius R_B ($<R_A$) are kept far apart and each is given charge $+Q$. Now they are connected by a thin metal wire. Then

(IIT-JEE 2011)

(a) $E_A^{\text{inside}}=0$ (b) $Q_A>Q_B$

(c) $\frac{\sigma_A}{\sigma_B}=\frac{R_B}{R_A}$ (d) $E_A^{\text{on surface}}<E_B^{\text{on surface}}$

16. Four point charges $+8\mu C$, $-1\mu C$, $-1\mu C$ and $+8\mu C$ are fixed at the points $-\sqrt{27/2}$ m, $-\sqrt{3/2}$ m, $+\sqrt{3/2}$ m, and $+\sqrt{27/2}$ m respectively on the y-axis. A particle of mass 6×10^{-4} kg and charge $+0.1\ \mu C$ moves along the x-direction. Its speed at $x=+\infty$ is v_0. Find the least value of v_0 for which the particle will cross the origin. Find also the kinetic energy of the particle at the origin. Assume that space is gravity free.

(IIT-JEE 2011)

17. Under the influence of the coulomb field of a fixed charge $+Q$, a charge $-q$ is moving around it in an elliptical orbit.
Find out the correct statement(s). **(IIT-JEE 2009)**

(a) The angular momentum of the charge $-q$ is constant

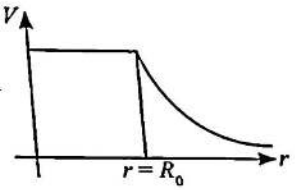
(b) The linear momentum of the charge $-q$ is constant

(c) The angular velocity of the charge $-q$ is constant

(d) The linear speed of the charge $-q$ is constant

18. For spherical symmetrical charge distribution, variation of electric potential with distance from centre is given in diagram. Given that

(IIT-JEE 2006)



@FREE CBSE X @RAJ EDUNET

$V = \frac{q}{4\pi\varepsilon_0 R_0}$ for $r \le R_0$ and $V = \frac{q}{4\pi\varepsilon_0 r}$ for $r \ge R_0$

Then, which option(s) are correct

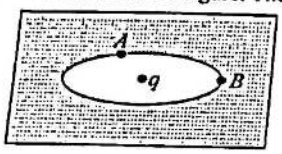
(a) Total charge within $2R_0$ is q

(b) Total electrostatic energy for $r \le R_0$ is zero

(c) At $r = R_0$ electric field is discontinuous

(d) There will be no charge anywhere except at $r = R_0$

19. An elliptical cavity is carved within a perfect conductor. A positive charge q is placed at the centre of the cavity. The points A and B are on the cavity surface as shown in the figure. Then **(IIT-JEE 1999)**



(a) electric field near A in the cavity = electric field near B in the cavity.

(b) charge density at A = charge density at B

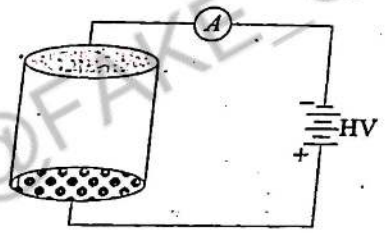
(c) potential at A = potential at B

(d) total electric field flux through the surface of the cavity is q/ε_0.

Comprehension Based/Passage Based

Passage

Consider an evacuated cylindrical chamber of height h having rigid conducting plates at the ends and an insulating curved surface as shown in the figure. A number of spherical balls made of a light weight and soft material and coated with a conducting material are placed on the bottom plate. The balls have a radius $r << h$. Now, a high voltage source (HV) connected across the conducting plates such that the bottom plate is at $+V_0$ and the top plate at $-V_0$. Due to their conducting surface, the balls will get charge, will become equipotential with the plate and are repelled by it. The balls will eventually collide with the top plate, where the coefficient of restitution can be taken to be zero due to the soft nature of the material of the balls. The electric field in the chamber can be considered to be that of a parallel plate capacitor. Assume that there are no collisions between the balls and the interaction between them is negligible. (Ignore gravity)



20. Which one of the following statement is correct?

C-24.55 W-72.59 UA-2.86 (JEE Adv. 2016)

(a) The balls will execute simple harmonic motion between the two plates.

(b) The balls will bounce back to the bottom plate carrying the same charge they went up with.

(c) The balls will stick to the top plate and remain there.

(d) The balls will bounce back to the bottom plate carrying the opposite charge they went up with.

21. The average current in the steady state registered by the ammeter in the circuit will be **C-27.51 W-69.94 UA-2.55 (JEE Adv. 2016)**

(a) proportional to V_0^2.

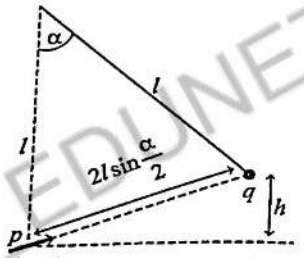
(b) proportional to the potential V_0.

(c) zero

(d) proportions to $V_0^{1/2}$

Numerical Types/Integer Types

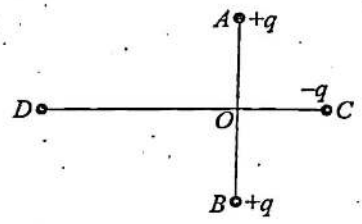
22. A point charge q of mass m is suspended vertically by a string of length l. A point dipole of dipole moment p is now brought towards q from infinity so that the charge moves away. The final equilibrium position of the system including the direction of the dipole, the angles and distances is shown in the figure below. If the work done in bringing the dipole to this position is $N \times (mgh)$, where g is the acceleration due to gravity, then the value of N is _____. (Note that for three coplanar forces keeping a point mass in equilibrium, $\frac{F}{\sin\theta}$ is the same for all forces, where F is any one of the forces and θ is the angle between the other two forces) **(JEE Adv. 2020)**



23. Three point charges q, $2q$ and $8q$ are to be placed on a 9 cm long straight line. Find the positions where the charges should be placed such that the potential energy of this system is minimum. In this situation, what is the electric field at the position of the charge q due to the other two charges? **(IIT-JEE 1987)**

24. Two fixed, equal, positive charges, each of magnitude $q = 5 \times 10^{-5}$ C are located at points A and B separated by a distance of 6 m. An equal and opposite charge moves towards them along the line COD, the perpendicular bisector of the line AB. The moving charge, when reaches the point C at a distance of 4 m from O, has a kinetic energy of 4 J. Calculate the distance of the farthest point D which the negative charge will reach before returning towards C.

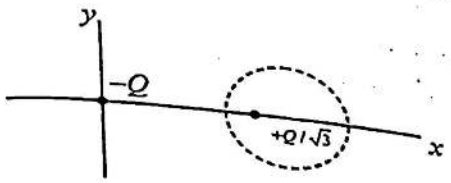
(IIT-JEE 1985)



Fill in the Blanks

25. Two point charges $-Q$ and $+Q/\sqrt{3}$ are placed in the xy-plane at the origin (0, 0) and a point (2, 0) respectively, as shown in the figure. This results in an equipotential circle of radius R and potential $V = 0$ in the xy-plane with its center at $(b, 0)$. All lengths are measured in meters. **(JEE Adv. 2021)**

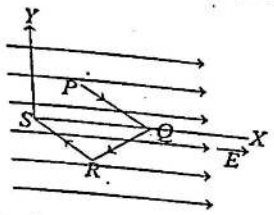
@FAKE_CODE@RAJ_EDUNET



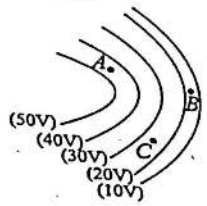
(*a*) The value of R is _____ meter. C-17.01 W-63.21 UA-19.78

(*b*) The value of b is _____ meter. C-23.8 W-56.77 UA-19.44

26. A point charge q moves from point P to point S along the path $PQRS$ (Fig.) in a uniform electric field E pointing parallel to the positive direction of the X-axis. The coordinates of points P, Q, R and S are $(a, b, 0)$, $(2a, 0, 0)$, $(a, -b, 0)$, $(0,0,0)$ respectively. The work done by the field in the above process is given by the expression ..... **(IIT-JEE 1989)**



27. Figure shows lines of constant potential in a region in which an electric field is present. The values of the potential are written in brackets. Of the points A, B and C, the magnitude of the electric field is greatest at the point..... **(IIT-JEE 1984)**



True/False

28. Two identical metallic spheres of exactly equal masses are taken. One is given a positive charge Q coulomb and the other an equal negative charge. Their masses after charging are different. **(IIT-JEE 1983)**

29. The work done in carrying a point charge from one point to another in an electrostatic field depends on the path along which the point charge is carried. **(IIT-JEE 1981)**

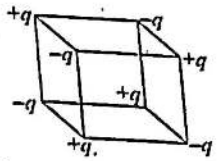
Subjective

30. A conducting bubble of radius a, thickness t ($t << a$) has potential V. Now the bubble collapses into a droplet. Find the potential of the droplet. **(IIT-JEE 2005)**

31. There are two large parallel metallic plates S_1 and S_2 carrying surface charge densities σ_1 and σ_2 respectively ($\sigma_1 > \sigma_2$) placed at a distance d apart in vacuum. Find the work done by the electric field in moving a point charge q a distance a ($a < d$) from S_1 towards S_2 along a line making an angle $\pi/4$ with the normal to the plates **(IIT-JEE 2004)**

32. A positive point charge q is fixed at origin. A dipole with a dipole moment p is placed along the x-axis far away from the origin with p pointing along positive x-axis. Find : (*a*) the kinetic energy of the dipole when it reaches a distance d from the origin, and (*b*) the force experienced by the charge q at this moment. **(IIT-JEE 2003)**

33. Eight point charges are placed at the corners of a cube of edge a as shown in figure. Find the work done in disassembling this system of charges. **(IIT-JEE 2003)**



34. A non-conducting disc of radius a and uniform positive surface charge density σ is placed on the ground with its axis vertical. A particle of mass m and positive charge q is dropped, along the axis of the disc from a height H with zero initial velocity. The particle has $q/m = 4\varepsilon_0 g/\sigma$. **(IIT-JEE 1999)**

(*a*) Find the value of H if the particle just reaches the disc.

(*b*) Sketch the potential energy of the particle as a function of its height and find its equilibrium position.

35. Two isolated metallic solid spheres of radii R and $2R$ are charged such that both of these have same charge density σ. The spheres are located far away from each other and connected by a thin conducting wire. Find the new charge density on the bigger sphere. **(IIT-JEE 1996)**

36. A circular ring of radius R with uniform positive charge density λ per unit length is located in the y-z plane with its centre at the origin O. A particle of mass m and positive charge q is projected from the point $P(R\sqrt{3}, 0, 0)$ on the positive x-axis directly towards O, with an initial speed v. Find the smallest (non-zero) value of the speed v such that the particle does not return to P. **(IIT-JEE 1993)**

37. (*a*) If the same charge of Q as in part (*a*) above is given to a spherical conductor of the same radius R, what will be the energy of the system?

(*b*) A charge of Q is uniformly distributed over a spherical volume of radius R. Obtain an expression for the energy of the system. Assume the earth to be a sphere of uniform mass density. Calculate this energy, given the product of the mass and the radius of the earth to be 2.5×10^{31} kg-m.

(*c*) What will be the corresponding expression for the energy needed to completely disassemble the planet earth against the gravitational pull amongst its constituent particles? **(IIT-JEE 1992)**

38. Two fixed charges $-2Q$ and Q are located at the points with coordinates $(-3a, 0)$ and $(+3a, 0)$ respectively in the x-y plane. **(IIT-JEE 1991)**

(*a*) Show that all points in the x-y plane where the electric potential due to the two charges is zero, lie on a circle. Find its radius and the location of its centre.

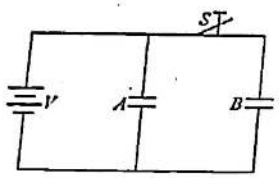
(*b*) Give the expression $V(x)$ at a general point on the x-axis and sketch the function $V(x)$ on the whole x-axis.

(*c*) If a particle of charge $+q$ starts form rest at the centre of the circle, show by a short quantitative argument that the particle eventually crosses the circle. Find its speed when it does so.

@TAKE CBSE X PRASHANT

39. The figure shows two identical parallel plate capacitors A and B connected to a battery with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric constant (or relative permittivity) 3. Find the ratio of the total electrostatic energy stored in both capacitors before and after the introduction of the dielectric

(IIT-JEE 1983)



40. A charge Q is distributed over two concentric hollow spheres of radii r and R ($> r$) such that the surface densities are equal. Find the potential at the common centre. (IIT-JEE 1981)

Relation Between Field and Potential

Single Correct

41. Two large vertical and parallel metal plates having a separation of 1 cm are connected to a DC voltage source of potential difference X. A proton is released at rest midway between the two plates. It is found to move at 45° to the vertical just after release. Then X is nearly C-14.28 W-25.75 UA 59.97 (IIT-JEE 2012)

(a) 1×10^{-5} V (b) 1×10^{-7} V (c) 1×10^{-9} V (d) 1×10^{-10} V

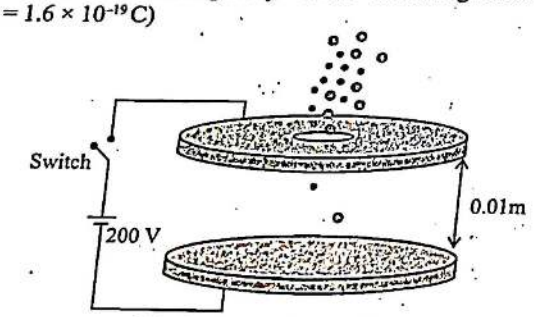
42. A non-conducting ring of radius 0.5 m carries a total charge of 1.11×10^{-10} C distributed non-uniformly on its circumference producing an electric field E everywhere in space. The value of the integral $\int_{l=\infty}^{l=0} -E \cdot dl$ ($l = 0$ being centre of the ring) in volt is

(IIT-JEE 1997)

(a) +2 (b) −1 (c) −2 (d) zero

Numerical Types/Integer Types

43. Two large circular discs separated by a distance of 0.01 m are connected to a battery via a switch as shown in the figure. Charged oil drops of density 900 kg m^{-3} are released through a tiny hole at the center of the top disc. Once some oil drops achieve terminal velocity, the switch is closed to apply a voltage of 200 V across the discs. As a result, an oil drop of radius 8×10^{-7} m stops moving vertically and floats between the discs. The number of electrons present in this oil drop is _____. (Neglect the buoyancy force, take acceleration due to gravity = 10 ms^{-2} and charge on an electron (e) = 1.6×10^{-19} C)

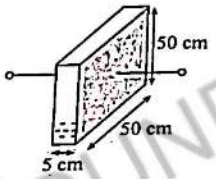


C-11.05 W-18.06 UA-70.89 (JEE Adv. 2020)

Capacitance, Parallel Plate Capacitor, Spherical Capacitor

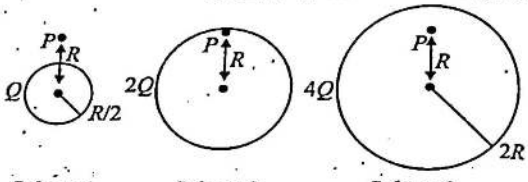
Single Correct

44. A container has a base of 50 cm × 5 cm and height 50 cm, as shown in the figure. It has two parallel electrically conducting walls each of area 50 cm × 50 cm. The remaining walls of the container are thin and non-conducting. The container is being filled with a liquid of dielectric constant 3 at a uniform rate of 250 cm^{3}s^{-1}. What is the value of the capacitance of the container after 10 seconds? [Given: Permittivity of free space $\epsilon_0 = 9 \times 10^{-12}$ C^{2}N^{-1}m^{-2}, the effects of the non-conducting walls on the capacitance are negligible] C-27.7 W-26.81 UA-45.48 (JEE Adv. 2023)



(a) 27 pF (b) 63 pF
(c) 81 pF (d) 135 pF

45. Charges Q, $2Q$ and $4Q$ are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii $R/2$, R and $2R$ respectively, as shown in figure. If magnitudes of the electric fields at point P at a distance R from the centre of spheres 1, 2 and 3 are E_1, E_2 and E_3 respectively, then C-52.72 W-40.69 UA-6.59 (JEE Adv. 2014)



Sphere-1 Sphere-2 Sphere-3

(a) $E_1 > E_2 > E_3$ (b) $E_3 > E_1 > E_2$
(c) $E_2 > E_1 > E_3$ (d) $E_3 > E_2 > E_1$

46. The magnitude of electric field E in the annular region of a charged cylindrical capacitor (IIT-JEE 1996)

(a) is same throughout.
(b) is higher near the outer cylinder than near the inner cylinder.
(c) varies as $1/r$ where r is the distance from the axis.
(d) varies as $1/r^2$ where r is the distance from the axis.

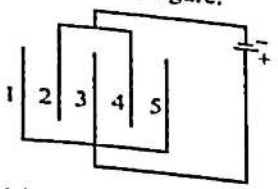
Fill in the Blanks

47. Two parallel plate capacitors of capacitances C and $2C$ are connected in parallel and charged to a potential difference V. The battery is then disconnected and the region between the plates of capacitor C is completely filled with a material of dielectric constant K. The potential difference across the capacitors now becomes....

(IIT-JEE 1988)

CBSE @RAY EDUNET

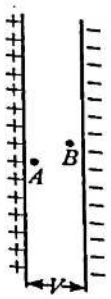
48. Five identical capacitor plates, each of area A, are arranged such that adjacent plates are at a distance d apart, the plates are connected to a source of emf V as shown in the figure. **(IIT-JEE 1984)**



The charge on plate 1 is ..... and on plate 4 is ..... .

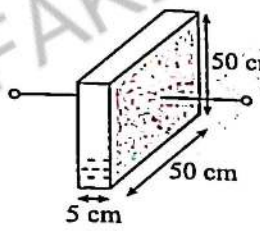
True/False

49. Two protons A and B are placed in between the two plates of a parallel plate capacitor charged to a potential difference V as shown in the figure. The forces on the two protons are identical. **(IIT-JEE 1986)**



Numerical Types/Integer Types

50. A container has a base of 50 cm × 5 cm and height 50 cm, as shown in the figure. It has two parallel electrically conducting walls each of area 50 cm × 50 cm. The remaining walls of the container are thin and non-conducting. The container is being filled with a liquid of dielectric constant 3 at a uniform rate of 250 cm^3s^{-1}. What is the value of the capacitance of the container after 10 seconds?
[Given: Permittivity of free space $\epsilon_0 = 9 \times 10^{-12}\ C^2N^{-1}m^{-2}$, the effects of the non-conducting walls on the capacitance are negligible]
C-27.7 W-26.81 UA-45.48 (JEE Adv. 2023)



51. A parallel plate capacitor of capacitance C has spacing d between two plates having area A. The region between the plates is filled with N dielectric layers, parallel to its plates, each with thickness $\delta = \frac{d}{N}$. The dielectric constant of the m^{th} layer is $K_m = K\left(1+\frac{m}{N}\right)$. For a very large N ($>10^3$), the capacitance C is $\alpha\left(\frac{K\epsilon_0 A}{d\ln 2}\right)$. The value of α will be _____[ϵ_0 is the permittivity of free space]
C-16 W-56 UA-29 (JEE Adv. 2019)

Subjective

52. A conducting sphere S_1 of radius r is attached to an insulating handle. Another conducting sphere S_2 of radius R is mounted on an insulating stand. S_2 is initially uncharged.
S_1 is given a charge Q, brought into contact with S_2 and removed. S_1 is recharged such that the charge on it is again Q and it is again brought into contact with S_2 and removed. This procedure is repeated n times. **(IIT-JEE 1998)**
(*a*) Find the electrostatic energy of S_2 after n such contacts with S_1.
(*b*) What is the limiting value of this energy as $n \to \infty$?

Combination of Capacitors

Single Correct

53. A medium having dielectric constant $K > 1$ fills the space between the plates of a parallel plate capacitor. The plates have large area, and the distance between them is d. The capacitor is connected to a battery of voltage V, as shown in Figure (*a*). Now, both the plates are moved by a distance of $d/2$ from their original positions, as shown in figure (*b*).
In the process of going from the configuration depicted in Figure (*a*) to that in Figure (*b*), which of the following statement(s) is/are correct? **C-17.88, W-45.49, UA-36.63 (JEE Adv. 2022)**

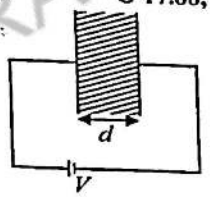


Figure (*a*)

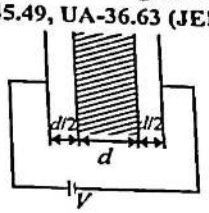
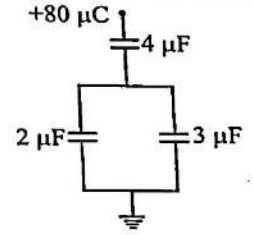


Figure (*b*)

(*a*) The electric field inside the dielectric material is reduced by a factor of $2K$
(*b*) The capacitance is decreased by a factor of $\frac{1}{K+1}$.
(*c*) The voltage between the capacitor plates is increased by a factor of $(K+1)$
(*d*) The work done in the process does not depend on the presence of the dielectric material

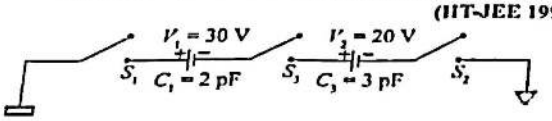
54. In the given circuit, a charge of +80 μC is given to the upper plate of the 4 μF capacitor. Then in the steady state, the charge on the upper plate of the 3 μF capacitor is
C-34.93 W-36.07 UA-29.01 (IIT-JEE 2012)



(*a*) +32 μC (*b*) +40 μC (*c*) +48 μC (*d*) +80μC

@FAKE CBSE @RAJ EDUNET

55. For the circuit shown, which of the following statements is true? **(IIT-JEE 1999)**



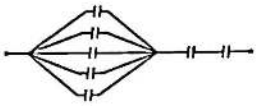
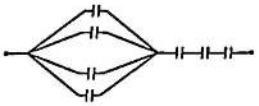
(a) With S_1 closed, $V_1' = 15$V, $V_2' = 20$V

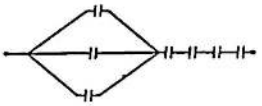
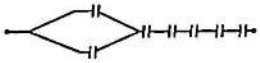
(b) With S_2 closed, $V_1' = V_2' = 25$V

(c) With S_1 and S_2 closed, $V_1' = V_2' = 0$

(d) With S_3 closed, $V_1' = 30$V, $V_2' = 20$V

56. Seven capacitors each of capacitance 2 μF are connected in a configuration to obtain an effective capacitance $\frac{10}{11}$ μF. Which of the following combination will achieve the desired result? **(IIT-JEE 1990)**

(a)  (b) 

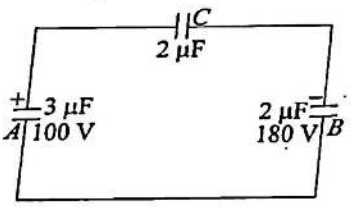
(c)  (d) 

Numerical Types/Integer Types

57. Parallel plate capacitor of capacitance C has spacing d between two plates having area A. The region between the plates is filled with N dielectric layers, parallel to its plates, each with thickness $\delta = \frac{d}{N}$. The dielectric constant of the m^{th} layer is $K_m = K\left(1+\frac{m}{N}\right)$. For a very large N (> 103), the capacitance C is $\alpha\left(\frac{K\epsilon_0 a}{d\ell n 2}\right)$. The value of α will be _____. **C-16 W-56 UA-29 (JEE Adv. 2019)**

Subjective

58. Two capacitors A and B with capacities 3 μF and 2 μF are charged to a potential difference of 100 V and 180 V respectively. The plates of the capacitors are connected as shown in the figure with one wire of each capacitor free. The upper plate of A is positive and that of B is negative. An uncharged 2 μF capacitor C with lead wires falls on the free ends to complete the circuit. Calculate **(IIT-JEE 1997)**



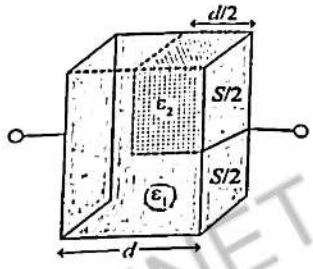
(a) the final charge on the three capacitors and

(b) the amount of electrostatic energy stored in the system before and after completion of the circuit.

Dielectric and Energy Stored in Capacitors

Single Correct

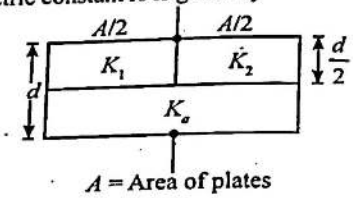
59. A parallel plate capacitor having plates of area S and plate separation d, has capacitance C_1 in air. When two dielectrics of different relative permittivities ($\varepsilon_1 = 12$ and $\varepsilon_2 = 4$) are introduced between the two plates as shown in the figure, the capacitance becomes C_2. The ratio $\frac{C_2}{C_1}$ is **(JEE Adv. 2015)**



(a) $\frac{6}{5}$ (b) $\frac{5}{3}$

(c) $\frac{7}{5}$ (d) $\frac{7}{3}$

60. A parallel plate capacitor of area A, plate separation d and capacitance C is filled with three different dielectric materials having dielectric constants K_1, K_2 and K_3 as shown. If a single dielectric material is to be used to have the same capacitance C in this capacitor then its dielectric constant K is given by **(IIT-JEE 2000)**



A = Area of plates

(a) $\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{2K_3}$

(b) $\frac{1}{K} = \frac{K_1 K_2}{K_1 + K_2} + 2K_3$

(c) $\frac{1}{K} = \frac{1}{K_1 + K_2} + \frac{1}{2K_3}$

(d) $K = \frac{K_1 K_3}{K_1 + K_3} + \frac{K_2 K_3}{K_2 + K_3}$

61. A parallel plate capacitor of capacitance C is connected to a battery and is charged to a potential difference V. Another capacitor of capacitance $2C$ is similarly charged to a potential difference $2V$. The charging battery is now disconnected and the capacitors are connected in parallel to each other in such a way that the positive terminal of one is connected to the negative terminal of the other. The final energy of the configuration is **(IIT-JEE 1995)**

(a) Zero (b) $\frac{3}{2}CV^2$ (c) $\frac{25}{6}CV^2$ (d) $\frac{9}{2}CV^2$

@FAKE_CBSE_X@REAL EDUNET

Multiple Correct

62. A parallel plate capacitor of plate area A and plate separation d is charged to potential difference V and then the battery is disconnected. A slab of dielectric constant K is then inserted between the plates of the capacitor so as to fill the space between the plates. If Q, E and W denote respectively, the magnitude of charge on each plate, the electric field between the plates (after the slab is inserted), and work done on the system, in question, in the process of inserting the slab, then **(IIT-JEE 1991)**

(a) $Q = \frac{\varepsilon_0 AV}{d}$

(b) $Q = \frac{\varepsilon_0 KAV}{d}$

(c) $E = V/Kd$

(d) $W = \frac{\varepsilon_0 AV^2}{2d}[1 - 1/K]$

63. A parallel plate capacitor is charged and the charging battery is then disconnected. If the plates of the capacitor are moved farther apart by means of insulating handles **(IIT-JEE 1987)**

(a) the charge on the capacitor increases

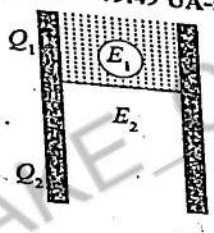
(b) the voltage across the plates increases

(c) the capacitance increases

(d) the electrostatic energy stored in the capacitor increases

64. A parallel plate capacitor has a dielectric slab of dielectric constant K between its plates that covers 1/3 of the area of its plates, as shown in the figure. The total capacitance of the capacitor is C while that of the portion with dielectric in between is C_1. When the capacitor is charged, the plate area covered by the dielectric gets charge Q_1 and the rest of the area gets charge Q_2. The electric field in the dielectric is E_1 and that in the other portion is E_2. Choose the correct option/ options, ignoring edge effects.

C-15.09 W-79.49 UA-5.43 (JEE Adv. 2014)



(a) $\frac{E_1}{E_2} = 1$

(b) $\frac{E_1}{E_2} = \frac{1}{K}$

(c) $\frac{Q_1}{Q_2} = \frac{3}{K}$

(d) $\frac{C}{C_1} = \frac{2+K}{K}$

65. A dielectric slab of thickness d is inserted in a parallel plate capacitor whose negative plate is at $x = 0$ and positive plate is at $x = 3d$. The slab is equidistant from the plates. The capacitor is given some charge. As x goes from 0 to $3d$ **(IIT-JEE 1998)**

(a) the magnitude of the electric field remains the same.

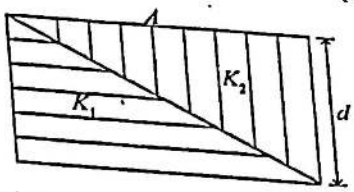
(b) the direction of the electric field remains the same.

(c) the electric potential increases continuously.

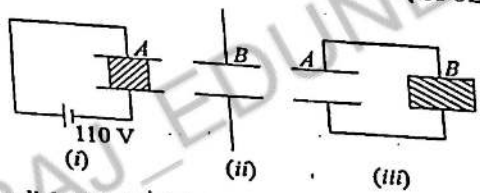
(d) the electric potential increases at first, then decreases and again increases.

Subjective

66. The capacitance of a parallel plate capacitor with plate area A and separation d, is C. The space between the plates is filled with two wedges of dielectric constants K_1 and K_2 respectively (figure). Find the capacitance of the resulting capacitor. **(IIT-JEE 1996)**



67. Two parallel plate capacitors A and B have the same separation $d = 8.85 \times 10^{-4}$ m between the plates. The plate areas of A and B are 0.04 m² and 0.02 m² respectively. A slab of dielectric constant (relative permittivity) $K = 9$ has dimensions such that it can exactly fill the space between the plates of capacitor B. **(IIT-JEE 1993)**



(a) The dielectric slab is placed inside A as shown in figure (*i*) A is then charged to a potential difference of 110V. Calculate the capacitance of A and the energy stored in it.

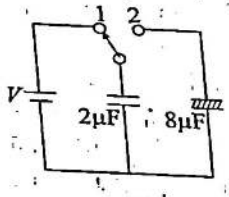
(b) The battery is disconnected and then the dielectric slab is removed from A. Find the work done by the external agency in removing the slab from A.

(c) The same dielectric slab is now placed inside B, filling it completely. The two capacitors A and B are then connected as shown in figure (*iii*). Calculate the energy stored in the system.

Sharing of Charge, Capacitor Circuits

Single Correct

68. A 2μF capacitor is charged as shown in the figure. The percentage of its stored energy dissipated after the switch S is turned to position 2 is **(IIT-JEE 2011)**



(a) 0%

(b) 20%

(c) 75%

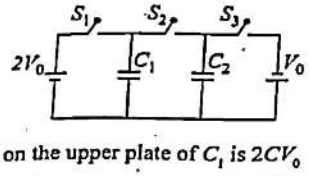
(d) 80%

@FAKE_CBSE_X @RAJ_EDUNET

Multiple Correct

69. In the circuit shown in the figure, there are two parallel plate capacitors each of capacitance C. The switch S_1 pressed first to fully charge the capacitor C_1 and then released. The switch S_2 then pressed to charge the capacitor C_2. After some time, S_2 released and then S_3 pressed. After some time

C-24.29 W-47.43 UA-28.28 (JEE Adv. 2013)



(a) The charge on the upper plate of C_1 is $2CV_0$

(b) The charge on the upper plate of C_1 is CV_0

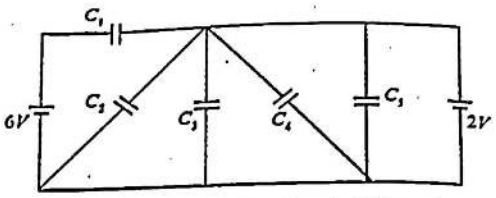
(c) The charge on the upper plate of C_2 is 0

(d) The charge on the upper plate of C_2 is CV_0

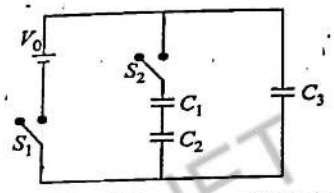
Numerical Types/Integer Types

70. In the following circuit $C_1 = 12\ \mu F$, $C_2 = C_3 = 4\ \mu F$ and $C_4 = C_5 = 2\ \mu F$. The charge stored in C_3 is _____ μC.

C-22.13, W-55.16, UA-22.71 (JEE Adv. 2022)



71. Three identical capacitors C_1, C_2 and C_3 have a capacitance of $1.0\mu F$ each and they are uncharged initially. They are connected in a circuit as shown in the figure and C_1 is then filled completely with a dielectric material of relative permittivity ε_r. The cell electromotive force (emf) $V_0 = 8V$. First the switch S_1 is



closed while the switch S_2 is kept open. When the capacitor C_3 is fully charged, S_1 is opened and S_2 is closed simultaneously. When all the capacitors reach equilibrium, the charge on C_3 is found to be $5\mu C$. The value of ε_r = ...

C-12.5 W-67.72 UA-19.79 (JEE Adv. 2018

@FREE CBSE X @RAJ EDUCET

ANSWER KEY

JEE-Main

1. [18]	2. (c)	3. [243]	4. (c)	5. (d)	6. (a)	7. (a)	8. (b)	9. (d)	10. (d)
11. [18]	12. (c)	13. [27]	14. (b)	15. [36]	16. (b)	17. (c)	18. (c)	19. (a)	20. [5]
21. [160]	22. [198]	23. (d)	24. (b)	25. (a, b, c)	26. (b)	27. (a)	28. [128]	29. (a)	30. (b)
31. (b)	32. (a)	33. (a)	34. (a)	35. (a)	36. [12]	37. (a)	38. (a)	39. (c)	40. (a)
41. (d)	42. [1.73, 3]	43. (d)	44. (a)	45. (b)	46. (b)	47. (b)	48. (c)	49. [2]	50. [750]
51. (a)	52. (c)	53. [105]	54. (c)	55. [6]	56. (b)	57. (c)	58. (a)	59. (a)	60. (d)
61. (a)	62. (a)	63. (d)	64. (c)	65. [3]	66. (d)	67. [0.99 to 1.01]	68. (c)	69. [864]	
70. [161]	71. (c)	72. (b)	73. (a)	74. [80]	75. (a)	76. (a)	77. (c)	78. [3]	79. (a)
80. (c)	81. [23]	82. (b)	83. (a)	84. (d)	85. (c)	86. (a)	87. (d)	88. (c)	89. (a)
90. (d)	91. (c)	92. [5]	93. [6]	94. (a)	95. [12]	96. (a)	97. [60]	98. (b)	99. (d)
100. (d)	101. (c)	102. (*)	103. [2]	104. (a)	105. (a)	106. (b)	107. (c)	108. [5]	109. [4]
110. (a)	111. (a)	112. [8]	113. (d)	114. (a)	115. (c)	116. (a)	117. (b)	118. [2]	119. (a)
120. [86]	121. (c)	122. [55]	123. [4]	124. [125]	125. (c)	126. (b)	127. [225]	128. [6]	129. [125]
130. (a)	131. (c)	132. (a)	133. [240]	134. [6]	135. (a)	136. (d)	137. (a)	138. [1.30]	139. (b)
140. (a)	141. [100]	142. (a)	143. (a)	144. [16]	145. (c)	146. [4]	147. (a)		

JEE-Advanced

1. (b)	2. (b)	3. (a)	4. (d)	5. (c)	6. (a)	7. (d)	8. (b)	9. (a,b,c)	10. (a, c)
11. (a, d)	12. (a, b, c)	13. (c, d)	14. (c, d)	15. (a,b,c,d)	17. (a)	18. (a,b,c,d)	19. (c, d)	20. (d)	21. (a)
22. [2]	23. [0]	24. [8.48]	28. [True]	29. [True]	41. (c)	42. (a)	43. [6]	44. (b)	45. (c)
46. (c)	49. [True]	50. [63]	51. [1]	53. (b)	54. (c)	55. (d)	56. (a)	57. [0.99 to 1.01]	
59. (d)	60. (c)	61. (b)	62. (a, c, d)	63. (b, d)	64. (a, d)	65. (b, c)	68. (d)	69. (b, d)	70. [8]
71. [1.5]									

EXPLANATIONS

JEE-Main

1. [18] The work done in rotating the electric dipole
$\Delta U = U_f - U_i$
$\Delta U = (-pE\cos(180°)) - (-pE\cos(0°))$
$= 2pE$
$\Delta U = 2 \times 6 \times 10^{-6} \times 1.5 \times 10^3 = 18\ mJ$

2. (c)

$\because W = \vec{F} \cdot \vec{S}$
$\Rightarrow W_E = q\vec{E} \cdot \vec{S}$
$= 2\times10^{-2}\left[30\hat{i} \cdot (-\hat{i})\right]$
$= 2\times10^{-2}(-30)$
$\Rightarrow W = -600\,mJ$

3. [243] As volume will same,
$27 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \Rightarrow R = 3r$
Using conservation of charge, $Q = 27q$
Now potential energy, $= U_r = \frac{q^2}{8\pi\varepsilon_0 r}$
$= U_R = \frac{Q^2}{8\pi\varepsilon_0 R} = \frac{27\times27\times q^2}{8\pi\varepsilon_0 (3r)}$
$= 243\left(\frac{q^2}{8\pi\varepsilon_0 r}\right) = 243U_r$
Hence the potential energy of bigger drop is 243 times of smaller drop

4. (c) $F = -\frac{dU}{dr} = -\left[\frac{6A}{r^7} - \frac{12B}{r^{13}}\right]$
$F = 0$
$\Rightarrow r = \left(\frac{2B}{A}\right)^{1/6}$
$U\left(at\ r = \left(\frac{2B}{A}\right)^{1/6}\right) = -\frac{A^2}{4B}$

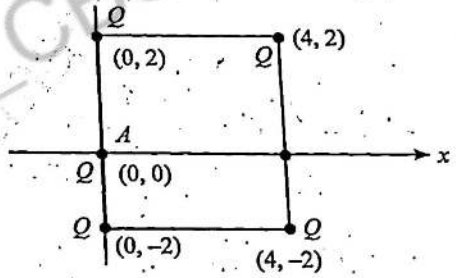
5. (d) $\frac{1}{2}mv^2 = mgy + \Delta U_{elec.}$
$\Delta U_{elec.} = kQq\left[\frac{1}{R} - \frac{1}{(R+y)}\right]$
$\Rightarrow v^2 = 2y\left[\frac{qQ}{4\pi\varepsilon_0 R(R+y)m} + g\right]$

6. (a) $U = -\frac{Kq^2}{d} + QV$
$V = -\frac{KP}{D^2} = -\frac{Kqd}{D^2}$;
$U = -\frac{Kq^2}{d} - \frac{KQqd}{D^2}$

7. (a) $U = \frac{kq^2}{a} + \frac{kQq}{a} + \frac{kQq}{\sqrt{2}a} = 0$
$-q = Q\left(1 + \frac{1}{\sqrt{2}}\right)$
$Q = \frac{-q(\sqrt{2})}{\sqrt{2}+1}$

8. (b)
$q_A = 1\mu c; q_B = 1\mu c, m_B = 4\times10^{-9}\,kg,$
$r_{AB} = 10^{-3}\,m$
$\frac{1}{2}M_B V^2 = kq_A q_B\left\{\frac{1}{10^{-3}} - \frac{1}{9\times10^{-3}}\right\}$
$\frac{1}{2}\times4\times10^{-9}V^2 = 9\times10^9\times10^{-6}\times10^{-6}$
$\times\frac{8}{9}\times10^3$
$V^2 = \frac{8}{2}\times10^9 = 4\times10^9$

9. (d) $V_A = \frac{kQ}{2} + \frac{kQ}{2} + \frac{kQ}{2^2+4^2} + \frac{kQ}{\sqrt{2^2+4^2}}$



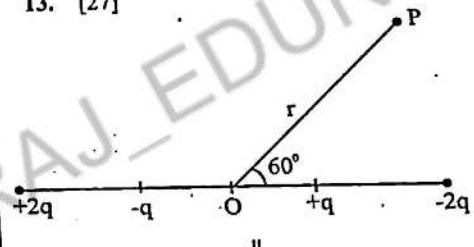
$V_A = \frac{kQ}{2} + \frac{kQ}{2} + \frac{kq}{\sqrt{2^2+4^2}} + \frac{kQ}{\sqrt{2^2+4^2}}$
$V_A = kQ + \frac{2kQ}{2\sqrt{5}}$
$PE = kQ^2\left(1 + \frac{1}{\sqrt{5}}\right) = \frac{Q^2}{4\pi\varepsilon_0}\left(1 + \frac{1}{\sqrt{5}}\right)$

10. (d) $\because \frac{Q^2}{4\pi\varepsilon_0 R_0} = \frac{Q^2}{4\pi\varepsilon_0 R} + \frac{1}{2}mv^2$
$\Rightarrow v = \sqrt{\frac{Q^2}{4\pi\varepsilon_0}\times\frac{2}{m}\left[\frac{1}{R_0} - \frac{1}{R}\right]}$
So v increases and attains a finite value after large time.

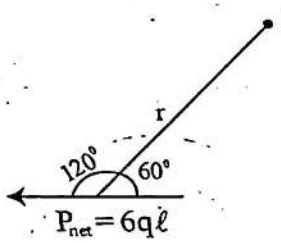
11. [18] The work done in rotating the electric dipole $= \Delta U = U_f - U_i$
$\Delta U = (-pE\cos(180°)) - (-pE\cos(0°)) = 2pE$
$\Delta U = 2 \times 6 \times 10^{-6} \times 1.5 \times 10^3 = 18\ mJ$

12. (c) $r_1 = \sqrt{(\sqrt{3})^2 + (\sqrt{3})^2}$
$r_2 = \sqrt{(\sqrt{6})^2 + 0}$
As $r_1 = r_2 = \sqrt{6}$
Potential difference $= \frac{KQ}{r_1} - \frac{KQ}{r_2}$
So potential difference $= 0$

13. [27]



$\Downarrow$
$P_1 = 2q\ell$ $\rightarrow$
$\leftarrow$ $P_2 = 8q\ell$



$P_{net} = 6q\ell$
Potential energy,
$V = \frac{K\vec{p}\cdot\vec{r}}{r^3} = \frac{9\times10^9(6q\ell)}{r^2}\cos(120°)$
$= -(27)\left(\frac{q\ell}{r^2}\right)\times10^9\,Nm^2c^{-2}$
$\Rightarrow \alpha = 27$

14. (b) As we know that,
$V = \frac{kP\cos\theta}{r^2}$
We can also check dimensionally.

@TAKE_CARE_X @RAJ_EDUNET

15. [36] Potential $V = \int K\frac{dQ}{R} = \frac{KQ}{R}$

$V = \frac{K\lambda\pi R}{R} \Rightarrow V = K\lambda\pi$

$\Rightarrow V = 9\times10^{9}\times4\times10^{-9}\pi$

$\therefore V = 36\pi$

16. (b) Potential at the centre of the half rings

$V = \frac{(\lambda\cdot\pi R_2)}{4\pi\varepsilon_0 R_2} + \frac{(\lambda\cdot\pi R_1)}{4\pi\varepsilon_0 R_1}$

$\Rightarrow V = \frac{\lambda}{2\varepsilon_0}$

17. (c) Electric Potential $V = \frac{Kq}{r}$

$\therefore r = \frac{Kq}{V}$

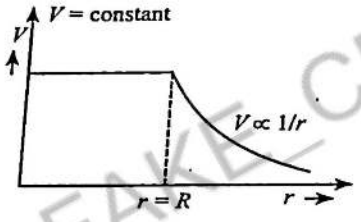
$r = \frac{9\times10^{9}\times5\times10^{-9}}{50}$

$r = \frac{45}{50} = \frac{9}{10} = 0.9m = 90cm$

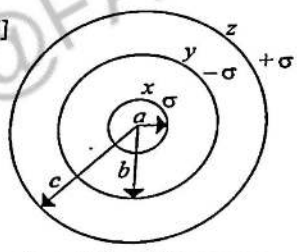
18. (c) Conceptual

19. (a)

Potential Inside	$V_{in} = \frac{KQ}{R}$
Potential at surface	$V_s = \frac{KQ}{R}$
Potential outside	$V_{out} = \frac{KQ}{r}$



20. [5]



Potenitial of X and Z are same.

$V_x = V_z$

$\frac{q_x}{4\pi\varepsilon_0 a} + \frac{q_y}{4\pi\varepsilon_0 b} + \frac{q_z}{4\pi\varepsilon_0 c}$

$= \frac{q_x}{4\pi\varepsilon_0 c} + \frac{q_y}{4\pi\varepsilon_0 c} + \frac{q_z}{4\pi\varepsilon_0 c}$

$\frac{\sigma 4\pi a^2}{a} - \frac{\sigma 4\pi b^2}{b} + \frac{\sigma 4\pi c^2}{c}$

$= \frac{4\pi\sigma\left[a^2 - b^2 + c^2\right]}{c}$

$c(a-b+c) = a - b^2 + c^2$

$c(a-b) = a^2 - b^2$

$c = (a+b)(a-b)/(a-b)$

$\Rightarrow c = a + b = 2 + 3 = 5$ cm

21. [160] Let radius of smaller drop be r and that of bigger drop be R
Let q = charge on each drop

$\therefore V = \frac{Kq}{r}$

Now for combination of 64 drop

Volume of 64 drops = volume of single drop

$64\times\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \ \therefore R = 4r$

Charge on bigger drop $Q = 64\,q$

Potential of bigger drop

$V' = \frac{KQ}{R} = \frac{K64q}{4r} = 16\frac{Kq}{r} = 16\times10\text{mV}$

$= 160\text{mV}.$

22. [198] $Q \to nq$

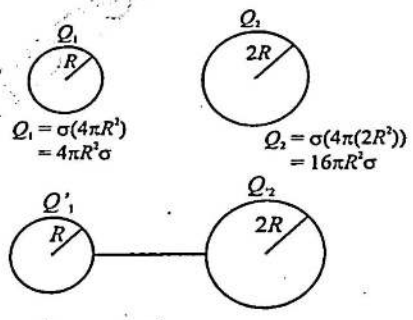
$n\frac{4}{3}\pi r^3 = \frac{4}{3}\pi(R)^3$ (volume of drop is equal)

$\Rightarrow R = rn^{\frac{1}{3}}$

$V = \frac{kq}{r} \propto \frac{n}{n^{1/3}} \propto n^{2/3} \propto 27^{2/3}$ (potential calculated)

$\Rightarrow V' = 9V = 9\times22 = 198$

23. (d)



$\frac{Q_1'}{4\pi\varepsilon_0 R} = \frac{Q_2'}{4\pi\varepsilon_0(2R)} \ \therefore Q_2' = 2Q_1'$

$Q_1' + Q_2' = Q_1 + Q_2$

$\therefore \frac{Q_2'}{2} + Q_2' = 20\pi R^2\sigma$

$\frac{3}{2}Q_2' = 20\pi R^2\sigma$

$\therefore \frac{Q_2'}{4\pi(2R)^2} = \frac{2}{3}\cdot\frac{20\pi R^2\sigma}{16\pi R^2}$

$\therefore \frac{\sigma'}{\sigma} = \frac{5}{6}$

24. (b) Let R = radius of combined drop,
r = radius of smaller drop
Volume will remain constant,

$\frac{4}{3}\pi R^3 = 64\times\frac{4}{3}\pi r^3$

$R = 4r$

q = charge of smaller drop

Q: Charge of combined drop

$\therefore Q = 64q;$

From the formula of surface charge density

$\frac{\sigma_{bigger}}{\sigma_{smaller}} = \frac{\frac{Q}{4\pi R^2}}{\frac{q}{4\pi r^2}} = \frac{Q}{q}\cdot\frac{r^2}{R^2}$ (Ratio of surface density)

$= 64\frac{r^2}{16r^2} = 4$

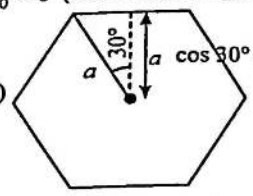
$\frac{\sigma_{bigger}}{\sigma_{smaller}} = \frac{4}{1}$

25. (a,b,c)

(a) Due to symmetry

$\overrightarrow{E_0} = 0$ (calculated using trigonometry)

(b)



$E_{net} = \frac{kq}{(2d)^2}\times2 = \frac{2q\times4}{4\pi\varepsilon_0\cdot4\cdot3a^2}$

$= \frac{q}{6\pi\varepsilon_0 a^2}$

(c) $V = \frac{7kq}{2d} = \frac{7q}{4\pi\varepsilon_0\cdot\sqrt{3}a} = \frac{7q}{4\sqrt{3}\pi\varepsilon_0 a}$

(Potential at O)

(d) $V = \frac{2kq}{2d} = \frac{2q}{4\pi\varepsilon_0\cdot\sqrt{3}a} = \frac{q}{2\sqrt{3}\pi\varepsilon_0 a}$

(Potential at O)

26. (b) For $r \in [0, 1]$; $\rho = kr$

For $r \in [1, r_B]$; $\rho = \frac{2k}{r}$

Total charge of the configuration is q

$q = \int_0^1 (kr)4\pi r^2 dr + \int_1^{r_B}\frac{2k}{r}4\pi r^2 dr$

$q = k\pi + 4k\pi\left(r_B^2 - 1\right)$

@FAKE_CBSE_K@RAJ_EDUNET

For $r_B = \sqrt{\frac{3}{2}}$; $q = k\pi + 2k\pi = 3k\pi$

Electric field just outside B is

$$E = \frac{1}{4\pi\epsilon_0}\frac{(3\pi k)}{r_B^2} = \frac{k}{2\epsilon_0}$$

For $r_B = \frac{3}{2}$; $q = k\pi + 2k\pi = 3k\pi$

Electric field just outside B is

$$E = \frac{1}{4\pi\epsilon_0}\frac{(3\pi k)}{r_B^2} = \frac{k}{2\epsilon_0}$$

For $r_B = \frac{3}{2}$; $q = k\pi + 5k\pi = 6k\pi$

Potential just outside B is, $V = \frac{(6\pi k)}{4\pi\epsilon_0\left(\frac{3}{2}\right)} = \frac{k}{\epsilon_0}$

For $r_B = 2$; $q = k\pi + 12k\pi = 13k\pi$

For $r_B = \frac{5}{2}$; $q = k\pi + 21k\pi = 22k\pi$

Magnitude of E just outside B is

$$\frac{1}{4\pi\epsilon_0}\frac{(22\pi k)}{\left(\frac{25}{4}\right)} = \frac{22}{25}\frac{k}{\epsilon_0}.$$

27. (*a*) Potential at the centre of ring A, due to charge $+Q$,

$$V_A = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{a} - \frac{1}{\sqrt{a^2+s^2}}\right] \quad \ldots (i)$$

Potential at the centre of ring B, due to charge $-Q$,

$$V_B = \frac{-Q}{4\pi\varepsilon_0}\left[\frac{1}{a} - \frac{1}{\sqrt{a^2+s^2}}\right] \quad \ldots (ii)$$

Subtracting (*i*) and (*ii*), we get,

$$V_A - V_B = \frac{Q}{2\pi\varepsilon_0}\left[\frac{1}{a} - \frac{1}{\sqrt{a^2+s^2}}\right]$$

28. [128] **Step-1:** Volume remains equal

Volume of small drop, $v = \frac{4}{3}\pi r^3$

Volume of large drop, $v = \frac{4}{3}\pi R^3$

Volume of 512 small drops

$$= 512 \times \frac{4}{3}\pi r^3$$

$$512 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$$\Rightarrow R = 8r$$

Step-2: Calculate the charge on large drop

Charge on large drop = 512 × charge on small drop

$Q = 512q$

Step-3: Calculate potential

Potential of small drop, $V' = \frac{kq}{r} = 2V$

Potential of large drop,

$$V'' = \frac{kQ}{R} = \frac{k(512q)}{8r} = 64\frac{kq}{r}$$

$$\Rightarrow V'' = 64 \times 2 = 128\,V'$$

Thus, the potential of the large drop is 128 V'.

29. (*a*) Let charges on shells be q_1 and q_2

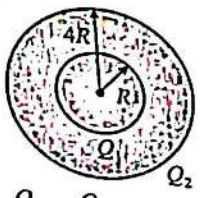
$q_1 + q_2 = Q$ ...(*I*)

$$\frac{q_1}{4\pi r^2} = \frac{q_2}{4\pi R^2} \quad \ldots (II)$$

We get $q_1 = \frac{r^2}{r^2+R^2}Q$, $q_2 = \frac{R^2}{r^2+R^2}Q$

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r} + \frac{q_2}{R}\right) = \frac{1}{4\pi\varepsilon_0}\frac{(R+r)}{(R^2+r^2)}Q$$

30. (*b*)



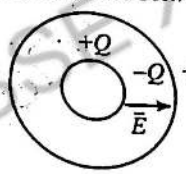
$$\therefore \frac{Q_1}{R^2} = \frac{Q_2}{16R^2} \Rightarrow Q_2 = 16Q_1$$

$$\left(\frac{KQ_1}{R} + \frac{KQ_2}{4R}\right) - \left(\frac{KQ_1}{4R} + \frac{KQ_2}{4R}\right) = V_1 - V_2$$

$$\Rightarrow V_1 - V_2 = \frac{3}{4} \times \frac{Q_1}{4\pi\varepsilon_0 R} = \frac{3Q_1}{16\pi\varepsilon_0 R}$$

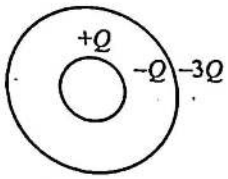
31. (*b*) In case-1

Electric field between spherical surface



In case-2

Electric field between surfaces remain unchanged.



$\therefore$ Potential difference between them remain unchanged too.

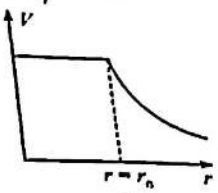
32. (*a*) $Q = \sigma 4\pi\left[a^2+b^2+c^2\right]$

$$V = \frac{1}{4\pi\varepsilon_0}\sigma\left[\frac{4\pi a^2}{a} + \frac{4\pi b^2}{b} + \frac{4\pi c^2}{c}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q(a+b+c)}{(a^2+b^2+c^2)}$$

33. (*a*) For spherical shell $V = \frac{K\cdot q}{r_0}, r \le r_0$

$= \frac{Kq}{r}, r > r_0$



34. (*a*) $V_0 = \frac{KQ}{R}$ (Potential at surface)

Potential at C

$$V_C = \frac{KQ}{R} - \frac{K\alpha Q}{R} = V_0(1-\alpha)$$

Potential at B

$$V_B = \frac{KQ}{R} - \frac{K(\alpha Q)}{R/2} = V_0(1-2\alpha)$$

$$\therefore \quad \frac{V_C}{V_B} = \frac{1-\alpha}{1-2\alpha}$$

Electric field at A

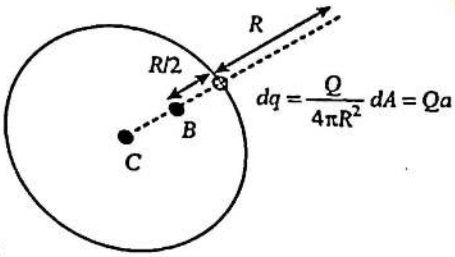
$$E_A = \frac{KQ}{(2R)^2} - \frac{K\alpha Q}{R^2} = \frac{KQ}{4R^2} - \frac{\alpha V_0}{R}$$

So electric field reduced by $\frac{\alpha V_0}{R}$

Electric field at C

$$E_C = \frac{K(\alpha Q)}{R^2} = \frac{\alpha V_0}{R}$$

So increased by $\frac{\alpha V_0}{R}$.



35. (*a*) Since potential of positive charge is always positive & electric field is a vector. So two electric field can be get cancelled if it has same magnitude & opposite direction.

36. [12] $\because E = -\frac{dV}{dr} = -4ar$

For a charged spherical ball $E = \frac{\rho r}{3\varepsilon_0}$

$\Rightarrow \rho = -12a\varepsilon_0$

Given, $\rho = -\lambda\alpha\varepsilon$

$\Rightarrow \lambda = 12$

37. (*a*) $\frac{E_1}{E_2} = \frac{R_1}{R_2}$

@FAKE_CBSE_X_@RAJ_EDUNET

$$\frac{V_1}{V_2}=\frac{E_1R_1}{E_2R_2}=\frac{R_1}{R_2}\times\frac{R_1}{R_2}=\left(\frac{R_1}{R_2}\right)^2$$

38. (a) $\Sigma q=0\Rightarrow V=0$
Also, field of one charge will get cancelled due to another symmetrical charge in front of it.

39. (c) $\vec{E}=K\frac{\vec{p}}{r^3}\sqrt{3\cos^2\theta+1}$

$\Rightarrow \theta=\pi/2\,(0,d,0)$

$\therefore \vec{E}=\frac{-k\vec{p}}{d^3}$

40. (a) $E=\frac{\lambda}{2\pi\varepsilon_0 r}$

$\int_{v_0}^{v_r}dv=\int-\frac{\lambda}{2\pi\varepsilon_0 r}dr$

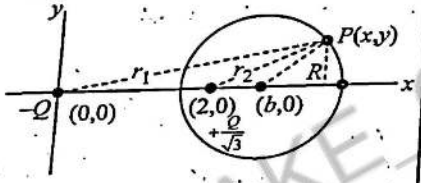
$\Rightarrow v_P-v_G=\frac{\lambda}{2\pi\varepsilon_0}\ln\frac{r}{r_0}$

$\frac{1}{2}mv^2=q\left(v_P-v_G\right)$

$\Rightarrow v\propto\left[\ln\left(\frac{r}{r_0}\right)\right]^{\frac{1}{2}}$

41. (d) So Angle between force and displacement will always be 90° as electric line of force are always perpendicular to equipotential surface. So work done equal to 0.

42. [1.73, 3]
Let point P on circle



$V_p=0=\frac{k(-Q)}{r_1}+\frac{kQ/\sqrt{3}}{r_2}$

$\frac{kQ}{r_1}=\frac{kQ/\sqrt{3}}{r_2}$

$\frac{1}{\sqrt{x^2+y^2}}=\frac{1}{\sqrt{3}\sqrt{(x-2)^2+y^2}}$

$x^2+6-6x+y^2=0$

$(x-3)^2+y^2=\left(\sqrt{3}\right)^2$

$R=\sqrt{3}=1.73,\ b=3$

43. (d) Electric potential $V=3x^2$

$E=-\frac{dV}{dx}$

$E=-\frac{d}{dx}(3x^3)$

$E=-6x$

At the point (1, 0, 2) electric field,
$E=-6\times1=-6$ V/m
Thus electric field at (1 m, 0, 2 m) is 6 Vm^{-1} along negative x-axis.

44. (a) $dV=-\vec{E}\cdot\overrightarrow{dr}=-(Ax+B)dx$

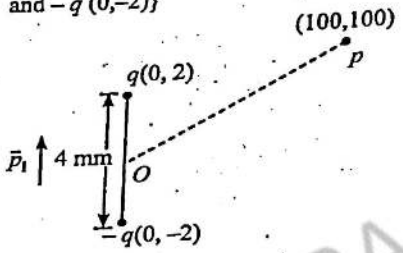
$\int_{V_2}^{V_1}dV=\int_{-5}^{1}-(Ax+B)dx$

$V_1-V_2=\left(-A\frac{x^2}{2}-Bx\right)_{-5}^{1}$

$=\left(-\frac{A}{2}-B\right)+\left(\frac{A}{2}25+B(-5)\right)$

$=12A-6B=240-60=180V$

45. (b) Case 1: Inital position of dipole {$q(0,2)$ and $-q\,(0,-2)$}



$\vec{p}_1=4q\,\hat{j}$

$\overrightarrow{OP}=\vec{r}=100\hat{i}+100\hat{j}$

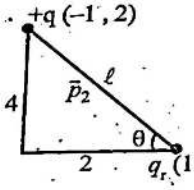
$V_{P_1}=\frac{k\vec{p}_1\cdot\vec{r}}{|\vec{r}|^3}$

Potential at P due to dipole

$=\frac{k\{(4q\hat{j})\cdot(100\hat{i}+100\hat{j})\}}{(100\sqrt{2})^3}$

$Vp_1=\frac{400kq}{(100\sqrt{2})^3}$ ...(i)

Case 2 : Final position of diode {$q(-1,2)$ and $-q(1,-2)$}



$\tan\theta=3\sin\theta=\frac{4}{5},\cos\theta=\frac{2}{5}$

$\vec{p}_2=5q(-\cos\theta\hat{i}+\sin\theta\hat{j})$

$\vec{r}=100\hat{i}+100\hat{j}$

Potential at P due to dipole

$Vp_2=\frac{K\vec{p}_2\cdot\vec{r}}{|\vec{r}|^3}$

$=\frac{K\{5q(-\cos\theta\hat{i}+\sin\theta\hat{j})\cdot(100\hat{i}+100\hat{j})\}}{(100\sqrt{2})^3}$

$Vp_2=\frac{500Kq(-\cos\theta+\sin\theta)}{(100\sqrt{2})^3}$ ...(ii)

Using equation (i) and (ii)

$\frac{Vp_2}{Vp_1}=\frac{500Kq(-\cos\theta+\sin\theta)}{(400Kq)}$

$=\frac{5}{4}\left(\frac{-2}{4}+\frac{4}{5}\right)$

$Vp_2=\frac{Vp_1}{2}=\frac{V_0}{2}$

46. (b) Here,

$(K.E.+P.E.)_{initial}=(K.E.+P.E.)_{final}$

$0+\left(\frac{1}{4\pi\epsilon_0}\frac{2P}{a^3}\right)\times P=2\times\frac{1}{2}mv^2+0$

$v=\sqrt{\frac{P^2}{2\pi\epsilon_0 ma^3}}=\frac{P}{a}\sqrt{\frac{1}{2\pi\epsilon_0 ma}}$

47. (b) Potential energy of electric dipole,

$U=\vec{P}\cdot\vec{E}=-PE\cos\theta$

$=-(10^{-29})\,(10^3)\cos45°$

$=-0.707\times10^{-26}\text{ J}=-7\times10^{-27}\text{ J}$

48. (c) $\vec{E}=K\frac{\vec{p}}{r^3}\sqrt{3\cos^2\theta+1}$

$\Rightarrow \theta=\pi/2\,(0,d,0)$

$\therefore \vec{E}=\frac{-k\vec{p}}{d^3}$

49. [2] Charge with no dielectric in capacitor is,

$Q=\frac{A\epsilon_0}{d}V$

Charge with dielectric in capacitor is,

$Q=\frac{A\epsilon_0 V}{d-t+\frac{t}{K}}$

From the given data,

$\frac{A\epsilon_0 V}{d-t+\frac{t}{K}}=(1.25)\frac{A\epsilon_0 V}{d}$

$\Rightarrow 1.25\left(3+\frac{2}{K}\right)=5$

$\Rightarrow K=2$

50. [750] Capacitance before inserting dielectric $C_0=12.5$ pF and charge on the capacitor $Q=C_0V$ After capacitance after inserting dielectric will become $\epsilon_r C_0$.

@RAKE_CBSE_X @RAJ_EDUNET

$\Delta E = E_i - E_f$

$= \frac{Q^2}{2C_i} - \frac{Q^2}{2C_f} = \frac{Q^2}{2C_0}\left[1 - \frac{1}{\epsilon_r}\right]$

$= \frac{(C_0V)^2}{2C_0}\left[1 - \frac{1}{\epsilon_r}\right] = \frac{1}{2}C_0V^2\left[1 - \frac{1}{\epsilon_r}\right]$

$= \frac{1}{2}(12.5)\times12^2\left[1 - \frac{1}{6}\right] = \frac{1}{2}(12.5) \times12^2 \times \frac{5}{6}$

$750\ pJ = 750 \times 10^{-12} J$

51. (a) Potential of a conducting sphere is given by,

$V' = \frac{KQ}{R}$

Given $V_1 = V_2$ and $R_1 = R_2$

$\therefore Q_1 = Q_2$

52. (c) From gauss's law $\phi = \frac{q_{in}}{\epsilon_0}$

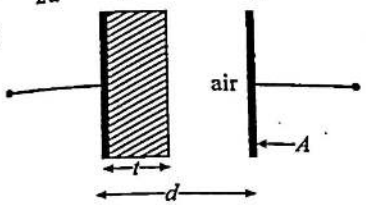
$= \frac{CV}{\epsilon_0}$

53. [105] Capacitance of capacitor with air between the plates $C_0 = \frac{\epsilon_0 A}{d} = 15pF$

Capacitance of capacitor with dielectric slab between the plates,

$C = \frac{K\epsilon_0 A}{2d} = \frac{3.5}{2} \times 15pF = \frac{105}{4}pF$

54. (c)



Above arrangement is similar as two capacitors in series combination so

$\Rightarrow \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$

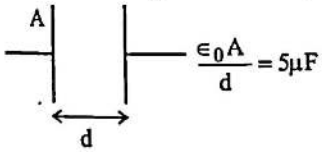
$= \frac{1}{\frac{K\epsilon_0 A}{t}} + \frac{1}{\frac{\epsilon_0 A}{d-t}}$

$= \frac{1\times10^{-3}}{5\epsilon_0 \times 40\times10^{-4}} + \frac{1\times10^{-3}}{\epsilon_0 \times 40\times10^{-4}}$

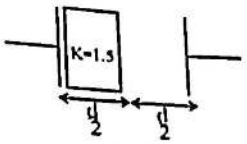
$\frac{1}{C_{eq}} = \frac{1}{20\epsilon_0} + \frac{1}{4\epsilon_0}$

$C_{eq} = \frac{20\times4\epsilon_0}{24} = \frac{10\epsilon_0}{3}F$

55. [6] For the capacitor having air between the plates $C = \frac{\epsilon_0 A}{d} = 5\mu F$



When a dielectric slab is inserted inside the capacitor

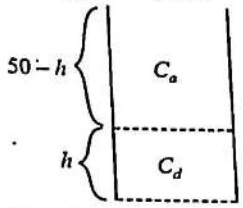


$C_{new} = \frac{\epsilon_0 A}{\frac{\left(\frac{d}{2}\right)}{1.5} + \frac{\left(\frac{d}{2}\right)}{1}}$

$= \frac{6\epsilon_0 A}{5d} = \frac{6}{5} \times 5\mu F = 6\mu F$

56. (b) Volume of liquid in 10s, $V = 2500cc$

$h = \frac{\text{Volume}}{\text{Area}} = \frac{2500}{50\times5} = 10\ cm$



Capacitance in dielectric

$C_d = \frac{A_d\epsilon_0 k}{d}$

$= \frac{50\times10^{-2}\times10\times10^{-2}\epsilon_0\times3}{5\times10^{-2}} = 3\epsilon_0$

Capacitance in air,

$C_a = \frac{A_a\epsilon_0}{d}$

$= \frac{50\times10^{-2}\times(50-10)\times10^{-2}\epsilon_0}{5\times10^{-2}} = 4\epsilon_0$

Net capacitance

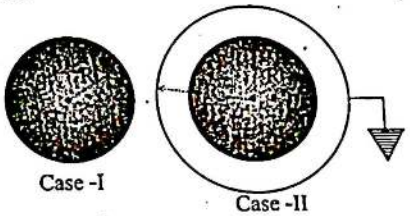
$C = C_a + C_d = 7\epsilon_0 = 7\times9\times10^{-12} = 63pF$

57. (c) $E = \frac{q_1 - q_2}{2A\epsilon_0}$ (between plates)

$V = Ed = \frac{(q_1 - q_2)}{2A\epsilon_0} = \frac{q_1 - q_2}{2C}$

$(\because C = \frac{A\epsilon_0}{d})$

58. (a)



Initially, $C_1 = 4\pi\epsilon_0 R_1$ and

Finally, $C_2 = \frac{4\pi\epsilon_0 R_2 R_1}{R_2 - R_1}$

According to question, $C_2 = nC_1$

$\Rightarrow \frac{C_2}{C_1} = n$

$\therefore \frac{4\pi\epsilon_0 R_1 R_2}{R_2 - R_1} \times \frac{1}{4\pi\epsilon_0 R_1} = n$

$\frac{R_2}{R_2 - R_1} = n$

$nR_2 - nR_1 = R_2$

$(n-1)R_2 = nR_1$

$\Rightarrow \frac{R_2}{R_1} = \frac{n}{n-1}$

59. (a) $E = \frac{\sigma}{\epsilon_0}$

$F = qE = \frac{q\sigma}{\epsilon_0} = 10N$

On removing one plate, electric field will become half; therefore, force will also become half. i.e.,

$F = \frac{10}{2} = 5N.$

60. (d) since force will act in horizontal direction so vertical component of speed will be same

$v_1\cos\alpha = v_2\cos\beta$

$\Rightarrow \frac{K_1}{K_2} = \left(\frac{v_1}{v_2}\right)^2 = \frac{\cos^2\beta}{\cos^2\alpha}$

61. (a) $g_{ff} = \sqrt{g^2 + \left(\frac{qE}{m}\right)^2}$

$T = 2\pi\sqrt{\frac{L}{g_{eff}}} = 2\pi\sqrt{\frac{L}{\sqrt{g^2 + \left(\frac{qE}{m}\right)^2}}}$

62. (a) Current $= \frac{dq}{dt}$ = slope of $q - t$ graph

At $t = 4$ sec

Slope = 0

$\therefore$ Current = 0

63. (d) $A = 30\pi cm^2 = 30\pi \times 10^{-4}m^2$

$d = 1\ mm = 10^{-3}\ m$

E = dielectric strength for breakdown

$= 3.6 \times 10^7\ V/m$

$Q = 7 \times 10^{-6}\ C$

Electric field, $E = \frac{\delta}{\epsilon_0}$

$E = \frac{Q}{kA\epsilon_0} \quad \because \sigma = \frac{Q}{A}$

$k = \frac{Q}{A\epsilon_0 E}$

$= \frac{7\times10^{-6}\times4\pi\times9\times10^9}{30\pi\times10^{-4}\times1\times3.6\times10^7} = \frac{70}{30} = 2.33$

@FAKE_CBSE_X @RAJ_EDUNET

64. (c) For $0 < x \le \frac{d}{2}$

$$dC_1 = \frac{(\varepsilon_0 + kx)A}{dx}$$

$$\int \frac{1}{dC_1} = \int \frac{dx}{(\varepsilon_0 + kx)A}$$

$$\frac{1}{C_1} = \frac{1}{A}\frac{[\ln(\varepsilon_0 + kx)]_0^{d/2}}{k}$$

$$= \frac{1}{kA}\ln\left(1 + \frac{kd}{2\varepsilon_0}\right)$$

$$C_1 = \frac{kA}{\ln\left(1 + \frac{kd}{2\varepsilon_0}\right)}$$

Similarly, For $\frac{d}{2} < x \le d$,

$$dC_2 = \frac{[\varepsilon_0 + k(d-x)]A}{dx}$$

$$\int \frac{1}{dC_2} = \int_{d/2}^{d} \frac{dx}{[\varepsilon_0 + k(d-x)]A}$$

$$= \frac{[\ln\{\varepsilon_0 + k(d-x)\}]_{d/2}^{d}}{-kA}$$

$$C_2 = \frac{kA}{\ln\left(1 + \frac{kd}{2\varepsilon_0}\right)} = C_1$$

let, $C_1 = C_2 = C$

then equivalent capacitance

$$= \frac{C_1 C_2}{C_1 + C_2} = \frac{C}{2} = \frac{kA}{2\ln\left(\frac{2\varepsilon_0 + kd}{2\varepsilon_0}\right)}$$

65. [3] The given capacitor can be considered as two capacitor (one with dielectric and another without dielectric) connected in parallel.

So, $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{d}{2k\varepsilon_0 A} + \frac{d}{2\varepsilon_0 A}$

$$\Rightarrow C_{eq} = \frac{2\varepsilon_0 Ak}{a(k+1)} = \frac{2\times 2\times 3.2}{4.2\times 1}\varepsilon_0$$

$$= 3.04\,\varepsilon_0$$

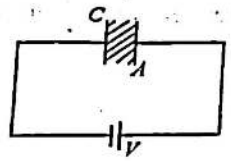
66. (d) $C = \frac{k\varepsilon_0 A}{d}$

$$k = \frac{Cd}{\varepsilon_0 A}$$

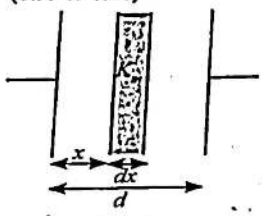
$$k = \frac{15\times 10^{-12}\times 500\times 10^{-6}}{8.86\times 10^{-12}\times 10^{-4}}$$

$$= \frac{75}{8.86} = 8.465$$

$k \approx 8.5$



67. (0.99 to 1.01)



$$\delta = dx = \frac{d}{N} \& \frac{m}{N} = \frac{x}{d}$$

$$K_m = K\left(1 + \frac{m}{N}\right), \Rightarrow K_m = K\left(1 + \frac{x}{d}\right)$$

$$C' = \frac{KmA\epsilon_0}{dx}$$

$$\frac{1}{C_{eq}}\int_0^d \frac{dx}{K_m A\epsilon_0} = \frac{1}{KA\epsilon_0}\int_0^d \frac{dx}{\left(1 + \frac{x}{d}\right)}$$

$$\Rightarrow \frac{1}{C_{eq}}\frac{dx}{K_m A\epsilon_0} = \left[\ell n\left(1 + \frac{x}{d}\right)\right]_0^d$$

$$\Rightarrow \frac{1}{C_{eq}}\frac{dx}{K_m A\epsilon_0} = [\ell n 2 - \ell n(1)]$$

$$\Rightarrow C_{eq} = \frac{K_m A\epsilon_0}{d\ell n 2} \Rightarrow \alpha = 1$$

68. (c) $E_{net} = \frac{E_0}{k}$, $\frac{q_f}{E_0} - \frac{q_b}{E_0} = \frac{q_f}{kE_0}$

$$q_b = q_f\left(1 - \frac{1}{k}\right)$$

69. [864]

$$U_{in} = \frac{CV^2}{2} = \frac{14\times 10^{-12}\times 12\times 12}{2}$$

$$= 1008\,pJ$$

When a porcelain plate with $k = 7$ is inserted between the plates, the capacitance of system becomes $C = kC$

$$U_f = \frac{Q^2}{2C'} = \frac{(CV)^2}{2kC} = \frac{CV^2}{2k}$$

$$= \frac{14\times 10^{-12}\times 12\times 12}{2\times 7} = 144\,pJ$$

Energy available for oscillation $U_{in} - U_f$
$= 1008 - 144 = 864\,pJ$

70. [161]

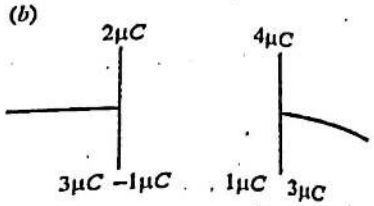
$$\frac{1}{C} = \frac{5}{\varepsilon_0\times 100} + \frac{5}{10\times\varepsilon_0\times 100}$$

$$\Rightarrow C = \frac{8.85\times 10^{-12}\times 1000}{55} = 161\text{ pF}$$

71. (c) $E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$

$Q = EA\varepsilon_0 = 100 \times 1 \times 8.85 \times 10^{-12}$
$= 8.85 \times 10^{-10}$ C

72. (b)

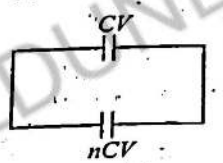


Charge at outer plates $= \frac{2+4}{2} = 3\mu C$

∴ Charges at inner plates are 1 μC and −1 μC.

Potential difference $= \frac{q}{C} = \frac{1\times 10^{-6}\text{C}}{1\times 10^{-6}\text{F}}$
$= 1$ V

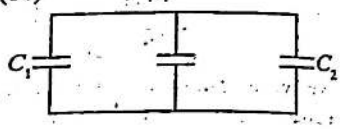
73. (a) Initially $Q = CV(1+n)$



$$\therefore C_{eq} = (K+n)C$$

$$\therefore V = \frac{CV(1+n)}{(K+n)C} = \frac{V(1+n)}{(K+n)}$$

74. (80)



$$C_1 = \frac{2\epsilon_0 A}{2\times d} = 10\mu F$$

$$C_2 = \frac{3\epsilon_0 A}{2d} = 15\mu F$$

$C_{eq} = C_1 + C_2 = 25\ \mu$F

Charge on C_1, Q_1=10 VμC

Charge on C_2, Q_2= 1.5 VμC

Now force between the plates

$$F = \frac{Q^2}{2A\epsilon_0}$$

$F_1 + F_2 = F$

$$\frac{100V^2\times 10^{-12}}{2\times 2\times 10^{-4}\epsilon_0} + \frac{225V^2\times 10^{-12}}{2\times 2\times 10^{-4}\epsilon_0} = 8$$

$$\frac{Q_1^2}{2A\epsilon_0} + \frac{Q_2^2}{2A\epsilon_0} = 8$$

$V = 0.93 \times 10^{-2}$ V

@FAIL_CBSE_X @RAJ_EDUVENT

75. (a) Capacitance of the capacitor,

$$\frac{A\varepsilon_0}{d}=\frac{A\varepsilon_0}{\left(0.2+\frac{d}{k}\right)}$$

$$0.6=0.2+\frac{0.6}{k}$$

Dielectric constant of the capacitor,

$$k=\frac{3}{2}$$

76. (a) $C_{eq}=C_1+C_2+C_3$

$$\Rightarrow C_{eq}=\frac{A\varepsilon_0}{3d}+\frac{A\varepsilon_0}{3(2d)}+\frac{A\varepsilon_0}{3(3d)}$$

$$=\frac{A\varepsilon_0}{3}\left(\frac{11}{6d}\right)$$

$$\therefore C_{eq}=\frac{11A\varepsilon_0}{18d}$$

77. (c) $K_{metal}=\infty, t=\frac{2d}{3}$

$$C_1=\frac{\epsilon_0 A}{d}=C$$

$$C_2=\frac{\epsilon_0 A}{d-t+\frac{t}{k_{metal}}}=\frac{\epsilon_0 A}{d-\frac{2d}{3}+0}$$

$$=3C_1=3C$$

$$\frac{C_2}{C_1}=\frac{3C}{C}=\frac{3}{1}$$

78. [3] For $x=\frac{d}{3}$

$$C_1=\frac{\epsilon_0 A}{\left(\frac{d/3}{k}+\frac{2d}{3}\right)}=\frac{\epsilon_0 A}{\frac{d}{12}+\frac{2d}{3}}$$

$$=\frac{\epsilon_0 A}{d}\times\left(\frac{12}{9}\right)$$

$$C_1=\frac{4}{3}\frac{\epsilon_0 A}{d}=2\mu F\Rightarrow\frac{\epsilon_0 A}{d}=\frac{6\mu F}{4}$$

for $x=\frac{2d}{3}$

$$C_2=\frac{E_0 A}{\left(\frac{2d/3}{k}+\frac{d}{3}\right)}=\frac{E_0 A}{d}\times 2$$

$$\Rightarrow\frac{6}{4}\times 2=3\mu F$$

79. (a) Initial Capacitance $C=\frac{A\varepsilon_0}{d}$

When sheet of thickness, $t=d/2$ is kept.

Then $C_{New}=\frac{A\varepsilon_0}{d-t}=\frac{A\varepsilon_0}{d/2}=\frac{2A\varepsilon_0}{d}$

$$\Rightarrow\frac{C_{New}}{C}=\frac{2}{1}$$

80. (c) Given, $C=\frac{\epsilon_0 A}{d}=4\mu F$

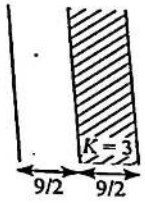
Formula of capacitance, $C=\frac{\epsilon_0 A}{d}$

$$\therefore C_1=\frac{\epsilon_0 A}{\frac{d}{2}}=4\times 2=8\mu F$$

$$C_2=\frac{k\epsilon_0 A}{d/2}=3\times 2\times 4=24\mu F$$

Since, C_1 and C_2 are in series, therefore.

$$C_{eq}=\frac{C_1C_2}{C_1+C_2}=\frac{8\times 24}{8+24}=\frac{8\times 24}{32}=6\mu F$$



81. [23] Capacitance of parallel plate capacitor

$$C=\frac{\epsilon_0 A}{d}$$

Where, d = distance between the plates of capacitor.

$$C_1=\frac{\epsilon_0 A}{5b}, C_2=\frac{\epsilon_0 A}{3b}, C_3=\frac{\epsilon_0 A}{b}$$

Since, capacitors are connected in parallel therefore,

$$C_{eq}=C_1+C_2+C_3=\frac{\epsilon_0 A}{b}\left[\frac{1}{5}+\frac{1}{3}+1\right]$$

$$C_{eq}=\frac{23}{15}\frac{\epsilon_0 A}{b}$$

82. (b) For series combination of capacitors of capacitance C_1 and C_2, $C_{eq}=\frac{C_1C_2}{C_1+C_2}$

$$\frac{C_1\times C_2}{C_1+C_2}=\frac{15}{4}(C_1+C_2)\Rightarrow 4C_1C_2$$

$$=15\left(C_1^2+C_2^2+2C_1C_2\right)$$

$$\Rightarrow 4\left(\frac{C_2}{C_1}\right)=15\left(\frac{C_2}{C_1}\right)^2+30\left(\frac{C_2}{C_1}\right)$$

$$+15\Rightarrow 15x^2+26x+15=0$$

Where, $x=\frac{C_2}{C_1}$

$$\Rightarrow x=\frac{-26\pm\sqrt{676-900}}{30}$$

Since x cannot be real, so this Question has been dropped by NTA

83. (a) Capacitors, C_1, C_2 and C_3 are in series therefore,

$$\frac{1}{C_{eq}}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$$

$$\frac{1}{C_{eq}}=\frac{1}{\left(\frac{k\Lambda\varepsilon_0}{d}\right)}+\frac{1}{\left(\frac{3k\Lambda\varepsilon_0}{2d}\right)}+\frac{1}{\left(\frac{5k\Lambda\varepsilon_0}{3d}\right)}$$

$$\frac{1}{C_{eq}}=\frac{d}{k\Lambda\varepsilon_0}+\frac{2d}{3k\Lambda\varepsilon_0}+\frac{3d}{5k\Lambda\varepsilon_0}$$

$$\frac{1}{C_{eq}}=\frac{(15+10+9)d}{15k\Lambda\varepsilon_0}$$

$$C_{eq}=\frac{15k\Lambda\varepsilon_0}{34d}$$

84. (d) $T\sin\theta=qE$ ... (i)

$T\cos\theta=mg$ ... (ii)

On dividing (i) by (ii) we get,

$$\tan\theta=\frac{qE}{mg}$$

$$Q=\frac{C_1C_2}{C_1+C_2}\cdot(V_1+V_2)$$

$$E=\frac{Q}{A\varepsilon_1}=\frac{C_1C_2}{C_1+C_2}\left[\frac{V_1+V_2}{A\varepsilon}\right]$$

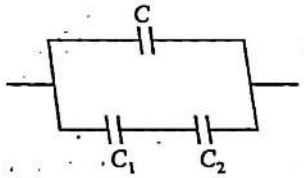
$$C_1=\frac{\varepsilon_0 A}{d-t}=\frac{C_2\left[V_1+V_2\right]}{(C_1+C_2)(d-t)}$$

$$\theta=\tan^{-1}\left[\frac{qE}{mg}\right]$$

$$\Rightarrow\theta=\tan^{-1}\left[\frac{q}{mg}\times\frac{C_2(V_1+V_2)}{(C_1+C_2)(d-t)}\right]$$

85. (c) Here, $C=\frac{\varepsilon_0 A}{2d}$, $C_1=\frac{k_1\varepsilon_0\frac{A}{2}}{\frac{d}{2}}=\frac{K_1\varepsilon_0 A}{d}$

and $C_2=\frac{k_2\varepsilon_0\frac{A}{2}}{\frac{d}{2}}=\frac{k_2\varepsilon_0 A}{d}$



$$C_{eq}=C+\frac{C_1\times C_2}{C_1+C_2}$$

On putting the value of C, C_1 and C_2 in the above equation, we get,

$$C_{eq}=\frac{\varepsilon_0 A}{d}\left(\frac{1}{2}+\frac{k_1k_2}{k_1+k_2}\right)$$

@FAKE_CBSE_X @RAJ_EDUNET

86. (a) Capacitance of element,

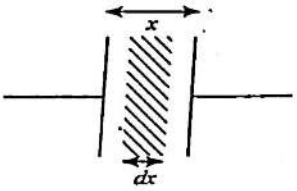
$$dc = \frac{K(1+\alpha x)\varepsilon_0 A}{dx}$$

As all elements are in series, so equivalent capacitance

$$\sum \frac{1}{c} = \int \frac{1}{dc} = \int_0^d \frac{dx}{k\varepsilon_0 A(1+\alpha x)}$$

$$\frac{1}{C} = \frac{1}{K\varepsilon_0 A\alpha} \ln\left(\frac{1+\alpha d}{1}\right)$$

Given: $\alpha d << 1$

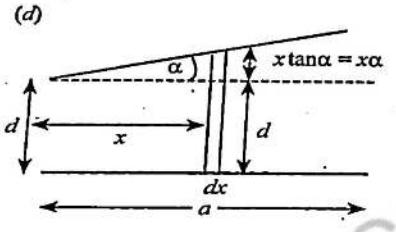


$$\frac{1}{C} = \frac{1}{K\varepsilon_0 A\alpha}\left(\alpha d - \frac{\alpha^2 d^2}{2}\right);$$

$$\Rightarrow \frac{1}{C} = \frac{d}{K\varepsilon_0 A}\left(1 - \frac{\alpha d}{2}\right)$$

$$\Rightarrow C = \frac{AK\varepsilon_0}{d}\left(1 + \frac{\alpha d}{2}\right)$$

87. (d)



We know that, $C = \frac{\varepsilon_0 A}{d}$

$$dC = \frac{\varepsilon_0 a dx}{d+\alpha x} \Rightarrow \int dC = \int \frac{\varepsilon_0 a dx}{d+\alpha x}$$

$$\Rightarrow C = \frac{\varepsilon_0 a}{\alpha}[\ln(d+\alpha x)]_0^a$$

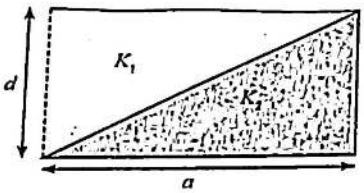
$$\Rightarrow C = \frac{\varepsilon_0 a}{\alpha}\ln\left(1+\frac{\alpha a}{d}\right) \approx \frac{\varepsilon_0 a^2}{d}\left(1-\frac{\alpha a}{2d}\right)$$

88. (c) $C = C_1 + C_2 + C_3$

$$\frac{\varepsilon_0 KA}{d} = \frac{\varepsilon_0 K_1 A}{3d} + \frac{\varepsilon_0 K_2 A}{3d} + \frac{\varepsilon_0 K_3 A}{3d}$$

$$\Rightarrow K = \frac{K_1 + K_2 + K_3}{3} = \frac{10+12+14}{3} = 12$$

89. (a) $C_{eq} = \dfrac{\varepsilon_0 K_1 K_2 a^2 \ln\frac{K_1}{K_2}}{(K_1 - K_2)d}$



$$\Rightarrow C_{eq} = \frac{\varepsilon_0 K a^2 \ln\frac{1}{K}}{d(1-K)}$$

As $K_1 = 1$, $K_2 = K$

$$\Rightarrow C_{eq} = \frac{\varepsilon_0 K a^2}{d(K-1)} \ln K$$

90. (d) $C_{eq} = \dfrac{C_1 C_2}{C_1 + C_2} + \dfrac{C_3 C_4}{C_3 + C_4}$, $C_1 = K_1.C$

$$C = \frac{\varepsilon_0 A/2}{d/2}$$

Similarly

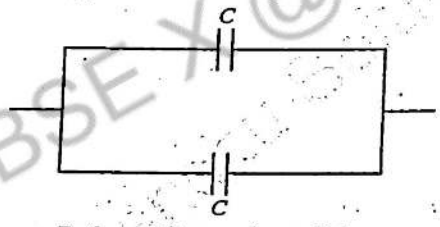
$$C_2 = K_2 C,\ C_3 = K_3 C,\ C_4 = K_4 C$$

$$K_{eq}\left(\frac{\varepsilon_0 A}{d}\right)$$

$$= \left(\frac{K_1 K_2}{K_1 + K_2} + \frac{K_3 K_4}{K_3 + K_4}\right)\frac{\varepsilon_0 A/2}{d/2}$$

$$\Rightarrow K_{eq} = \frac{K_1 K_2}{K_1 + K_2} + \frac{K_3 K_4}{K_3 + K_4}$$

91. (c) Reduced circuit is,



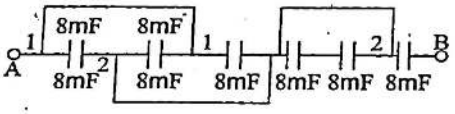
Both capacitors are in parallel.

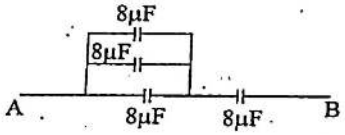
$\therefore C_{total} = C + C = 2C$

92. [5] $C = \dfrac{\in_0 A}{(d-c)} = \dfrac{\in_0 \times 200\times10^{-4}}{4\times10^{-3}} = 5\in_0$

$\therefore x = 5$

93. [6]





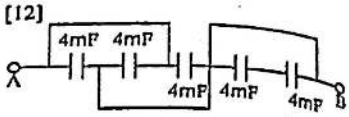
$$C_{eq} = \frac{24\times8}{32} = 6\ \mu F$$

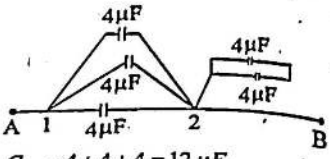
94. (a) $C_{eq} = \dfrac{C_1 C_2}{C_1 + C_2} = \dfrac{40\times40K}{40(1+K)} = 24$

$\Rightarrow 40K = 24 + 24K$

$\Rightarrow K = \dfrac{24}{16} = 1.5$

95. [12]





$C_{eq} = 4+4+4 = 12\ \mu F$

96. (a) We know that,

$$C_0 = \frac{\varepsilon_0 A}{d}$$

$$C_1 = \frac{4\varepsilon_0 A}{d} = 4C_0,$$

$$C_2 = \frac{K\varepsilon_0 A}{\frac{3}{4}d} = \frac{4kc_0}{3}$$

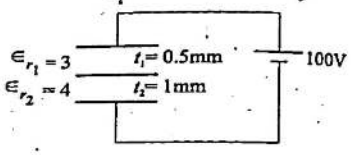
Series-

$$C_o = \frac{C_1 C_2}{C_1 + C_2}$$

$$\frac{16K}{3d}\frac{C_0^2}{4C_0\left(1+\frac{K}{3}\right)} = \frac{4KC_0.3}{3(K+3)} = \frac{4KC_0}{K+3}$$

97. [60] Capacitance of each capacitor

$$C_1 = \varepsilon_{r_1}\frac{\varepsilon_0 A}{t_1} = 6A\varepsilon_0, C_2 = \frac{\varepsilon_{r_2}\varepsilon_0 A}{t} = 4A\varepsilon_0$$



Equivalent capacitance

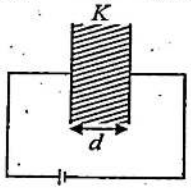
$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = \frac{24}{10}A\varepsilon_0$$

$$q_{Net} = C_{eq}(\Delta V) = 240A\varepsilon_0$$

$$\Delta V_2 = \frac{240A\varepsilon_0}{4A\varepsilon_0} = 60V$$

$$V_{roll} = 60V$$

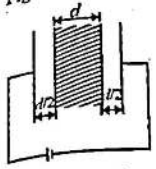
98. (b) For figure (a)



@TAKE_CBSE_X@RAJ_EDUNET

$E_0 = \frac{V}{d}; C = \frac{K\varepsilon_0 A}{d}$

Figure (b)

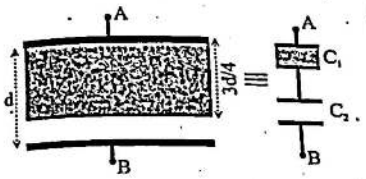


$C' = \frac{\varepsilon_0 A}{2d - d + d/K}$;

$C' = \frac{K\varepsilon_0 A}{(K+1)d}; C' = \frac{C}{K+1}$

99. (d) $C_1 = \frac{\varepsilon_0 Ak}{3d/4} = \frac{4\varepsilon_0 Ak}{3d} = \frac{4kC_0}{3}$

$C_2 = \frac{\varepsilon_0 A}{d/4} = \frac{4\varepsilon_0 A}{d} = 4C_0$



Since capacitors C_1 and C_2 are in series, so

$Ceq = \frac{C_1C_2}{C_1+C_2} = \frac{\frac{4kCo}{3}\times 4Co}{\frac{4kCo}{3}+4Co}$

$= \frac{4k}{k+3}Co$

100. (d) Formula of common potential

$V_c = \frac{Q_1+Q_2}{C_1+C_2} = \frac{C_1V_1+C_2V_2}{C_1+C_2}$

$V_c = \frac{2CV+CV}{KC+2C}$

$= \frac{3CV}{(K+2)C} = \frac{3V}{K+2}$

101. (c) When capacitors are connected in series, equivalent capacitance,

$C_1 = \frac{C\times C}{C+C} = \frac{C}{2}$

When capacitors are connected in parallel, equivalent capacitance

$C_2 = C + C = 2C$

$\frac{C_1}{C_2} = \frac{C/2}{2C} = \frac{1}{4}$

102. (*) For series combination of capacitors of capacitance C_1 and C_2, $C_{eq} = \frac{C_1C_2}{C_1+C_2}$

$\frac{C_1\times C_1}{C_1+C_2} = \frac{15}{4}(C_1+C_2) \Rightarrow 4C_1C_2$

$= 15(C_1^2+C_2^2+2C_1C_2)$

$\Rightarrow 4\left(\frac{C_2}{C_1}\right) = 15\left(\frac{C_1}{C_1}\right)^2 + 30\left(\frac{C_2}{C_1}\right)$

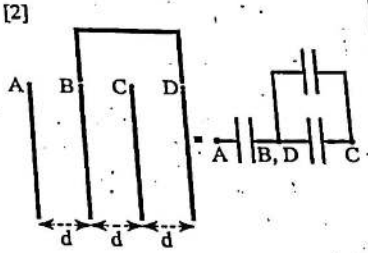
$+15 \Rightarrow 15x^2+26x+15 = 0$

Where, $x = \frac{C_2}{C_1}$

$\Rightarrow x = \frac{-26\pm\sqrt{676-900}}{30}$

Since x cannot be real, so this Question has been dropped by NTA. Its is bonus.

103. [2]

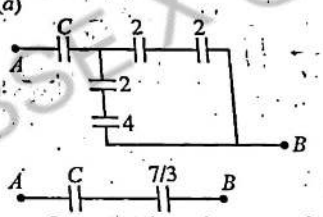


$C_{AC} = C_{eg} = \frac{C\times 2C}{e+2C} = \frac{2}{3}C$

$C_{AC} = \frac{2\varepsilon_0 A}{3d} = \frac{2\varepsilon_0\times 2\times 10^{-2}\times\frac{3}{2}\times 10^{-2}}{3d}$

$= \frac{2\varepsilon_0}{d}\times\times 10^{-4}\ F$

104. (a)



$\frac{\frac{7}{3}C}{C+\frac{7}{3}} = \frac{1}{2}$

$\Rightarrow 14C = 3C+7 \Rightarrow C = \frac{7}{11}\mu F$

105. (a) Equivalent capacitance for series combination

$C' = \frac{C_1C_2}{C_1+C_2}$

For parallel combination $C'' = C_1+C_2$

Also $C'' > C'$

$C_1+C_2 = \frac{500}{10} = 50\ \mu F$

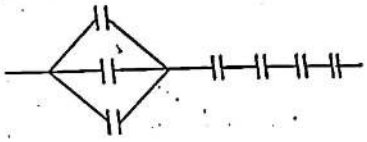
and $\frac{C_1C_2}{C_1+C_2} = \frac{80}{10} = 8\mu F$

$\therefore C_1C_2 = 400\mu F$

Solving $C_1 = 40\ \mu F C_2 = 10\ \mu F$

106. (b) $C_{eq} = \frac{6}{13}\mu F$

Therefore three capacitors most be in parallel to get 6 In



$\frac{1}{C_{eq}} = \frac{1}{3C}+\frac{1}{C}+\frac{1}{C}+\frac{1}{C}+\frac{1}{C}$

$C_{eq} = \frac{3C}{13} = \frac{6}{13}\mu F$

107. (c) $\frac{1}{C_1} = \frac{d}{3A\varepsilon_0}\left(\frac{1}{K_1}+\frac{1}{K_2}+\frac{1}{K_3}\right)$

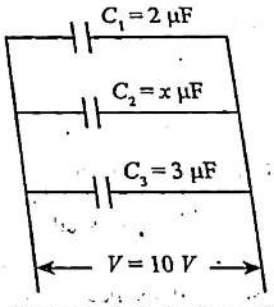
$C_1 = \frac{3A\varepsilon_0(K_1K_2K_3)}{d(K_1K_2+K_2K_3+K_3K_1)}$

$C_2 = \frac{A\varepsilon_0}{3d}(K_1+K_2+K_3)$

$\frac{E_1}{E_2} = \frac{C_1}{C_2} = \frac{3K_1K_2K_3}{(K_1K_2+K_2K_3+K_3K_1)} \times\frac{3}{(K_1+K_2+K_3)}$

$\Rightarrow \frac{E_1}{E_2} = \frac{9K_1K_2K_3}{(K_1+K_2+K_3)(K_1K_2+K_2K_3+K_3K_1)}$

108. [5]



Charge on C_1 is $Q_1 = C_1V = 2\times 10 = 20\mu C$

Charge on C_2 is $Q_2 = C_2V\times 10 = 10x\mu C$

Charge on C_3 is $Q_3 = C_3V = 30\mu C$

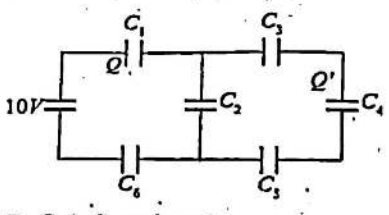
Total charge $Q = Q_1+Q_2+Q_3$

$100 = 20+10x+30$

$\Rightarrow x = 5$

@FAKE_CBSE_X @RAJ_ELINET

109. [4]



C_3, C_4 & C_5 are in series

$$\therefore \frac{1}{C}=\frac{1}{C_3}+\frac{1}{C_4}+\frac{1}{C_5}$$

$$=\frac{1}{2}+\frac{1}{4}+\frac{1}{2}\Rightarrow C=\frac{4}{5}=0.8\mu F$$

Now, C and C_2 are in parallel, therefore,

$C' = C + C_2 = 0.8 + 0.2 = 1\ \mu F$

Now, C', C_1 and C_6: are in series.

$$\frac{1}{C_{eq}}=\frac{1}{C'}+\frac{1}{C_1}+\frac{1}{C_6}=\frac{1}{1}+\frac{1}{2}+\frac{1}{2}$$

$$=2\Rightarrow C_{eq}=0.5\mu F$$

$Q = 0.5 \times 10 = 5\ \mu C$

$$Q'=\frac{5\mu C\times 0.8}{0.8+0.2}=4\mu C$$

110. (*a*) Equivalent capacitance of the system

$C_{eq} = C_1 + C_2 + C_3 + C_4$

$= 1 + 2 + 4 + 3 = 10\mu F$

Charge,

$Q = C_{eq} V$

$= (10 \times 20)\mu C$

$Q = 200\mu C$

111. (*a*) Equivalent capacitance,

$$\frac{1}{C_{eq}}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}=\frac{1}{10}+\frac{1}{15}+\frac{1}{20}$$

$$\frac{1}{C_{eq}}=\frac{6+4+3}{60}=\frac{13}{60}$$

$$C_{eq}=\frac{60}{30}\mu F$$

Total charge in the circuit

$$Q=C_{eq}V=\frac{60}{13}\times 13\mu C=60\mu C$$

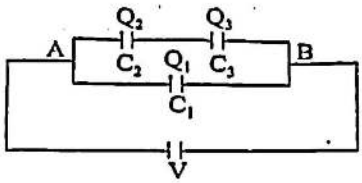
112. [8] Potential difference across the terminals of C_3 is $2V$

$\therefore Q_3 = CV = (4\mu)(2) = 8\mu C$

113. (*d*) We have given, $C_1 = 2\mu_F$, $C_2 = 6\mu F$ and $C_3 = 12\mu F$

$Q_1 = C_1 V = 2V\mu C$

$$Q_2 = Q_3 = \frac{C_2 C_3}{C_2 + C_3} V = \frac{6\times 12}{6+12} V = 4V\mu C$$

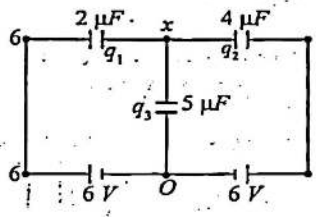


$Q_1 : Q_2 : Q_3 = 2V\mu C : 4V\mu C : 4V\mu C$

$= 1 : 2 : 2$

114. (*a*) Using junction analysis

We can say, $q_1 + q_2 + q_3 = 0$



We now $Q = CV$ [Where, C ix capacitance and V is voltage across the capacitor]

$2(x-6) + 4(x-6) + 5(x) = 0$

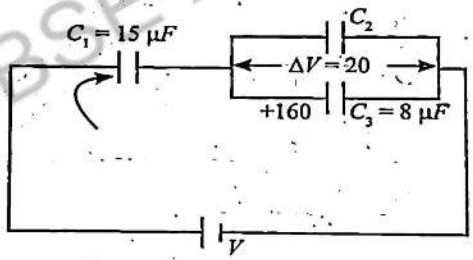
$$x=\frac{36}{11}\Rightarrow q_3=\frac{-36(5)}{11}=\frac{180}{11}$$

$q_3 = 16.36\mu C$

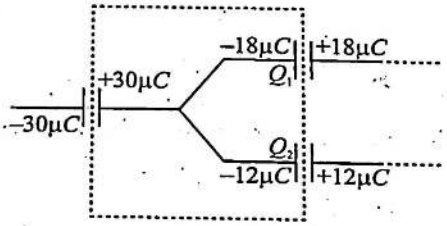
115. (*c*) As potential difference across c_2 and c_3 are equal

So $Q_3 = cv = 160\ \mu C$

$\therefore Q_2 = 750\ \mu C - 160\ \mu C = 590\ \mu C$ [$\because Q_1 = Q_2 + Q_3$]



116. (*a*) Let charge be Q_1 and Q_2

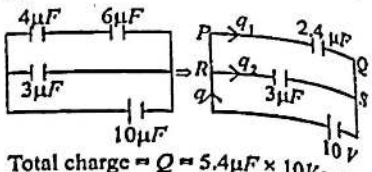


$$\frac{Q_1}{6}=\frac{Q_2}{4}$$

$\Rightarrow Q_1 + Q_2 = 30$

$\Rightarrow Q_1 = 18\mu C, Q_2 = 12\mu C$

117. (*b*)



Total charge = $Q = 5.4\mu F \times 10V = 54_{\mu P}$

The charge in branch PQ, Q_{PQ}

$= 2.4\mu F \times 10\ V = 24\mu C$

Since $4\mu F$ is in series with $6\mu F$

$(= 1\mu F \| 5\mu F)$, So $\theta_{4\mu F} = 24\mu C$

118. [2] As we know that,

$$\text{Energy loss} = \frac{1}{2}\frac{C_1 C_2}{C_1 + C_2}(V_1 - V_2)^2$$

Hence, $\text{Energy loss} = \frac{2}{3}\cdot E$

$\therefore x = 2$

119. (*a*) $C_{net} = 2C$

$$V_C = \frac{q_{net}}{C_{net}} = \frac{CV + 2CV}{2C} = \frac{3V}{2}$$

Therefore, decrease in energy of the combined system,

$$=\frac{1}{2}CV^2+\frac{1}{2}C(2V)^2-\frac{1}{2}2C\left(\frac{3V}{2}\right)^2$$

$$=\left(\frac{CV^2}{4}\right)$$

120. [86] In parallel combination : Potential difference is same across all capacitors = $V = 100$ V

$$U=\frac{1}{2}(C_1+C_2+C_3)V^2$$

$$=\frac{1}{2}(25+30+45)\times(100)^2\times 10^{-6}$$

$= 0.5 = E$

In series combination: Charge is same on all capacitors.

$$\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$$

$$=\frac{1}{25}+\frac{1}{30}+\frac{1}{45}=C=\frac{450}{43}$$

$$U=\frac{Q^2}{2C_1}+\frac{Q^2}{2C_2}+\frac{Q^2}{2C_3}$$

$$=\frac{Q^2}{2}\left[\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}\right]$$

$$=\frac{(V\times C)^2}{2}\times\frac{1}{C}=\frac{V^2C}{2}$$

$$=\frac{(100)^2}{2}\times\frac{450}{43}\times 10^{-6}$$

@FAKE_CBSE_K@RAJ_EDUNET

$$\Rightarrow \frac{4.5}{86}=\frac{9}{x}E=\frac{9}{x}\times 0.5$$

$$\Rightarrow x=86$$

121. (c) we have given that the two charged conducting spheres of radii a and b are connected to each other by a conducting wire.

Their potential will be equal

$$\frac{Kq_1}{a}=\frac{Kq_2}{b}$$

$$\frac{q_1}{q_2}=\frac{a}{b}$$

122. [55] As source is connected in the process therefore, additional charge will be provided. Therefore, charge on $C_1 = K(CV)$.

Since source is disconnected, so its charge will remain the same. Then, Charge on $C_2 = CV$.

New capacitance in both cases will become, KC.

When they are connected in parallel charge will be equally divided so charge on one capacitor is.

$$q=\left(\frac{K+1}{2}\right)CV$$

So common potential,

$$V'=\frac{q}{KC}=\frac{K+1}{2K}V=55V.$$

123. [4] Battery is connected while dielectric is inserted so potential difference will be remains same

$$U_i=\frac{1}{2}cV^2$$

$$U_f=\frac{1}{2}KcV^2$$

$$\Rightarrow \Delta U=\frac{1}{2}(K-1)cV^2$$

$$=\frac{1}{2}\times 1\times 200\times 10^{-9}\times 200^2=4$$

124. [125] Electrostatic Energy loss,

$$=\frac{1}{2}\frac{C_1\cdot C_2}{C_1+C_2}(V_1-V_2)^2$$

$$=\frac{1}{2}\times\frac{50\times10^{-12}\times50\times10^{-12}}{50\times10^{-12}+50\times10^{-12}}\times(100-0)^2$$

$$=125\times10^{-9}J=125\,nJ$$

125. (c) Given: $C_1 + C_2 = 10\ \mu F$ ...(i)

Energy stored in the capacitor $=\frac{1}{2}CV^2$

So, according to given condition

$$4\left(\frac{1}{2}C_1V^2\right)=\frac{1}{2}C_2V^2$$

$$\Rightarrow 4C_1=C_2$$ ...(ii)

From equation (i) and (ii)

$C_1 = 2\mu F$

$C_2 = 8\mu F$

C_{eq} in series $=\frac{C_1C_2}{C_1+C_2}=1.6\ \mu F$

126. (b) Initially, Charge on capacitor

$Q_1 = CV = 2V$

Energy stored

$$E_1=\frac{Q_1^2}{2C}=\frac{4V^2}{2\times2}=V^2$$

$E_1 = 1/2CV^2 = 1/2\,(2)V^2 = V^2$

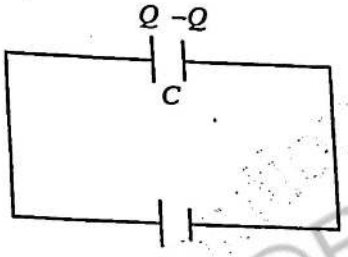
Finally

Charge on each capacitor,

$$Q_2=\frac{Q_1}{2}=\frac{2V}{2}=V$$

$$E_2=2\left(\frac{1}{2}\frac{Q_2^2}{C}\right)=\frac{V^2}{2}\quad\therefore\frac{E_2}{E_1}=\frac{1}{2}$$

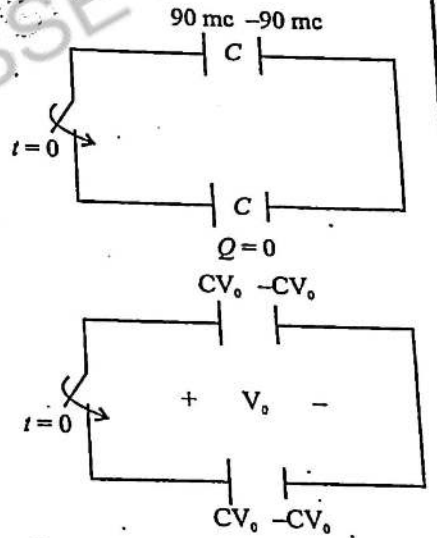
127. [225]



$C = 900\mu F$

$Q = CV = 900\times10^{-6}\times100 = 9\times10^{-2} = 90\,MC$

Now

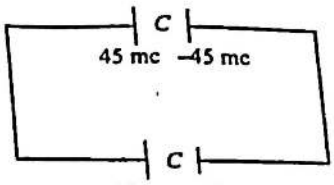


Common potential will be developed across both capacitors by kVL

Total charge on left plates of capacitors should be conserved.

$\therefore 90mc + 0 = 2cvv_0$

$cv_0 = 45mc$



Heat dissipated $= U_i - U_f$ [Change in energy stored in the capacitors]

$$=\frac{1}{2}\frac{(90mc)^2}{900\mu F}-2\times\frac{1}{2}\frac{(45mc)^2}{900\mu F}\left[U=\frac{Q^2}{2c}\right]$$

$$=\frac{1}{2\times900\times10^{-6}}(8100-4050)\times10^{-6}$$

$= 2.25$ Joule

OR

$$\text{Heat}=\frac{1}{2}\frac{C_1C_2}{C_1+C_2}(V_1-V_2)^2$$

$$=\frac{1}{2}\frac{C^2}{2C}(100-0)^2$$

$$=\frac{1}{2}\frac{900\times10^{-6}}{2}\times10^4=\frac{9}{4}$$

Joule $= 2.25$ Joule

128. [6] Formula of electrostatic loss of energy

$$\text{Energy lost}=\frac{1}{2}\frac{C_1\cdot C_2}{C_1+C_2}(V_1-V_2)^2$$

$$=\frac{1}{2}\times\left(\frac{600\times600}{600+600}\right)\times(200)^2$$

$$=6\times10^6\times10^{-12}\text{J}=2\times10^{-6}\text{J}=6\mu\text{J}$$

129. [125] Electrostatic Energy loss,

$$=\frac{1}{2}\frac{C_1\cdot C_2}{C_1+C_2}(V_1-V_2)^2$$

$$=\frac{1}{2}\times\frac{50\times10^{-12}\times50\times10^{-12}}{50\times10^{-12}+50\times10^{-12}}\times(100-0)^2$$

$$=125\times10^{-9}\,J$$

$$=125\,nJ$$

130. (a) Let us suppose,

Initial charge on capacitor, $q_1 = q$

Final charge on capacitor, $q_2 = q + 2$

According to the question,

$$\frac{U_2-U_1}{U_1}=\frac{44}{100}\Rightarrow\frac{\frac{(q+2)^2}{2C}-\frac{q^2}{2C}}{\frac{q^2}{2C}}=\frac{44}{100}$$

$$\Rightarrow\frac{(q+2)^2-q^2}{q^2}=\frac{44}{100}$$

$$\Rightarrow\left(1+\frac{2}{q}\right)^2-1=\frac{44}{100}\Rightarrow\left(1+\frac{2}{q}\right)^2=\frac{144}{10}$$

$$\Rightarrow\left(1+\frac{2}{q}\right)=\frac{12}{10}\Rightarrow\frac{2}{q}=0.2\Rightarrow q=10$$

@FAKE_CBSE_X @RAJ_EDUNET

131. (c) Case (I): When switch is closed, both capacitor are in parallel and energy stored.
$C_{eq} = 2C$

Energy, $E_1 = \frac{1}{2} \times C_{eq} \times V^2 = CV^2$

Case (II): When switch is opened, one charge get disconnected.

$$E_2 = \frac{1}{2} \times (5C) \times V^2 + \frac{(CV)^2}{2 \times 5C} = \frac{13}{5} CV^2$$

$\therefore$ Required ratio, $\frac{E_1}{E_2} = \frac{5}{13}$

132. (a) $U = \frac{1}{2} CV^2$

It is given that, voltage is constant

$$\therefore \frac{U_2}{U_1} = \frac{C_2 V_2^2}{C_1 V_1^2} = \frac{\frac{\epsilon_2 A}{d} \times V_2^2}{\frac{\epsilon_1 A}{d} \times V_1^2}$$

$$\Rightarrow \frac{U_2}{U_1} = \frac{\epsilon_2}{\epsilon_1} \Rightarrow \frac{U_2}{U_1} = \frac{15}{10}$$

$$\Rightarrow \left(\frac{U_2}{U_1} - 1\right) \times 100$$

$$= \left(\frac{15}{10} - 1\right) \times 100 = 50\%$$

133. [240] Equivalent capacitance, C_{eq}.

$$= \left[\frac{\varepsilon_0 (7 \times 4)}{4/10} + \frac{5\varepsilon_0 (1 \times 4)}{4/10}\right] \times 10^{-2}$$

$C_{eq} = 1.2\varepsilon_0$

Electrostatic energy $= \frac{1}{2} C_{eq} V^2$

$$= \frac{1}{2} (1.2\varepsilon_0)(20)(20) = 240\varepsilon_0$$

134. [6] Let the final p.d across the combination of capacitor be V'

$\therefore$ From the conservation of charge

$C \times 18 + 3C \times 18 = 9C \times V' + 3C \times V'$

$(\because K = 9)$

$72\ CV = 12\ CV' \Rightarrow V' = 6\ V$

135. (a) We know that, $Q_0 = CV_0$ [C is capacitance, V_0 is voltage]

Energy stored in the capacitor initially

$$U_i = \frac{1}{2} CV_0^2$$

$$q_1 = \frac{Q_0 C}{C + \frac{C}{2}} = \frac{2Q_0}{3}, q_2 = \frac{Q_0 \frac{C}{2}}{C + \frac{C}{2}} = \frac{Q_0}{3}$$

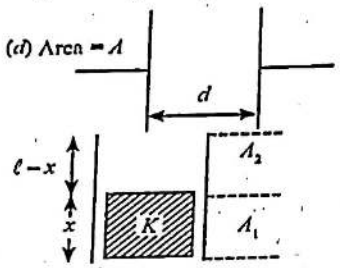
Energy stored in the capacitor finally

$$U_f = \frac{q_1^2}{2C} + \frac{q_2^2}{\frac{2C}{2}} = \frac{CV_0^2}{3}$$ [By putting value of q_1 and q_2]

Energy loss in the process $= U_i - U_f$

$$= \frac{1}{2} CV_0^2 - \frac{CV_0^2}{3} = \frac{CV_0^2}{6}$$

136. (d) Area $= A$



Before inserting slab, $C_i = \frac{\varepsilon_0 \ell w}{d}$

After inserting dielectric slab $C_f = C_1 + C_2$

$$C_f = \frac{K\varepsilon_0 A_1}{d} + \frac{\varepsilon_0 A_2}{d}$$

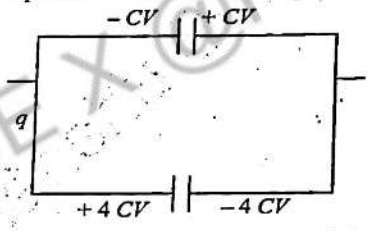
$$C_f = \frac{K\varepsilon_0 wx}{d} + \frac{\varepsilon_0 w(\ell - x)}{d}$$

$$C_f = \frac{2\varepsilon_0 \ell w}{d} = 2C_i$$

$$\because \frac{U_1}{U_2} = 2$$

$$\therefore 4x + \ell - x = 2\ell \Rightarrow x = \frac{\ell}{3}$$

137. (a) Here, we have given two capacitor of capacitance C and $2C$



$$V_{common} = \frac{4CV - CV}{3C} = V$$

$$C_{eq} = C + 2C = 3C$$

$$\therefore V_f = \frac{1}{2} \times (3C) \times V^2 = \frac{3}{2} CV^2$$

138. [1.30] $U = \frac{1}{2} \frac{C_1 C_2}{C_1 + C_2} V^2$

Let $C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$

$$\frac{1}{C_{eq} \pm \Delta C_{eq}} = \frac{1}{C_1 \pm \Delta C_1} + \frac{1}{C_2 \pm \Delta C_2}$$

$$= \frac{1200\left(1 \pm \frac{12}{1200}\right)}{\left(1 \pm \frac{25}{500}\right)}$$

$$= 1200\left[1 \pm \left(\frac{1}{100} - \frac{1}{200}\right)\right]$$

$$\frac{\Delta U}{U} \times 100 = \frac{\Delta C_{eq}}{C_{eq}} \times 100 + \frac{2\Delta V}{V} \times 100$$

$$= \frac{1}{200} \times 100 + 2 \times \frac{0.02}{5} \times 100 = 1.3\%$$

139. (b) $U = \frac{1}{2} CV^2 = \frac{1}{2} \times (12 \times 10^{-12}) \times (10)^2$

$U = 6 \times 10^{-10}\ J$

$U_i = U = 6 \times 10^{-10}\ J$

$$U_f = \frac{U}{k} = \frac{6 \times 10^{-10}}{6.5}$$

$U_f = 0.0923 \times 10^{-10}$

Work done $W = U_f - U_i$

$W = 6 \times 10^{-10} - 0.0923 \times 10^{-10}$

$W = 507.69\ pJ$

140. (a) Work done = change in potential energy

$\Delta W = U_f - U_i$

$$= \frac{q^2}{2}\left(\frac{1}{C_f} - \frac{1}{C_i}\right)$$

$$= \frac{(5 \times 10^{-6})^2}{2}\left(\frac{1}{2 \times 10^{-6}} - \frac{1}{5 \times 10^{-6}}\right)$$

$= 3.75 \times 10^{-6}$ J.

141. [100] Initially, charge on C_1, $q_1 = C_1 V$
$= 5 \times 10^{-6} \times 30 = 150\ \mu C$

After connecting with C_2, according the conservation of charge,

Total charge $= 150\ \mu C$

$\Rightarrow q_1 + q_2 = 150\ \mu C$ ...(i)

At equillibrium,

Voltage across C_1 = Voltage across C_2

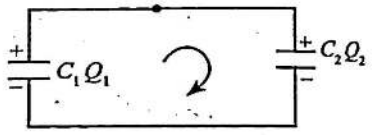
$$\frac{q_1}{C_1} = \frac{q_2}{C_2} \Rightarrow \frac{q_1}{5} = \frac{q_2}{10}$$

$\Rightarrow q_2 = 2q_2$ ...(ii)

$q_2 = 100\ \mu C$.

On solving (i) and (ii), we get

142. (a) After swith S is closed



$Q_1 + Q_2 = C_1 V$ ...(i)

using kirchhoffs volatage low

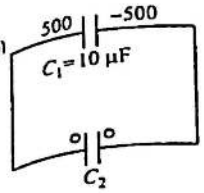
$$\frac{Q_1}{C_1} - \frac{Q_2}{C_2} = 0$$

$$Q_1 = Q_2 \frac{C_1}{C_2}$$ ...(ii)

from (i) and (ii)

$$Q_2 \frac{C_1}{C_2} + Q_2 = C_1 V \Rightarrow Q_2 = \left(\frac{C_1 C_2}{C_1 + C_2}\right) V$$

PLANE CBSE X @RAJ EDUNET



Here $C_1 = 10\ \mu F$

By charge conservation,

$(50)(10) + 0 = (20)(10) + (20)C_2$

$\Rightarrow 500 = 20(10 + C_2)$

$\Rightarrow 25 = 10 + C_2 \Rightarrow C_2 = 15\ \mu F$

144. [16] Let charge on C_2 be $q\mu C$.

Therefore, $\frac{q}{8} = \frac{2\times 10 - q}{2} \Rightarrow q = 16$

145. (c) According to conservation of charge

$Q_1 + Q_2 = 12\ \mu C - 3\ \mu C = 9\ \mu C$

As $v_1 = v_2$

$\Rightarrow \frac{kQ_1'}{\frac{2R}{3}} = \frac{kQ_2'}{\frac{R}{3}}$ [0 → Q]

$\Rightarrow Q_2' = \frac{Q_1'}{2}$

[Q_1' and Q_2' are the charges on spheres after connected by a conducting wire]

$\Rightarrow 2Q_2' + Q_2' = 9\ \mu C \Rightarrow Q_2' = 3\ \mu C$

Hence $Q_1' = 6\ \mu C$

146. [4] $C_1 = 5\mu F$, $V_1 = 220$ Volt

$C_2 = 2.5\ \mu F$, $V_2 = 0$

Heat loss; $\Delta H = U_i - U_f$

$= \frac{1}{2}\frac{C_1C_2}{C_1 + C_2}(V_1 - V_2)^2$

$\frac{1}{2}\times\frac{5\times 2.5}{(5+2.5)}(220-0)^2\ \mu J = 4\times 10^{-2}\ J$

$= \frac{4}{100}\ J$

Hence, value of X is 4.

Note: Given answer by JEE Main is $x = 36$

147. (a) $\Delta H = \Delta U$

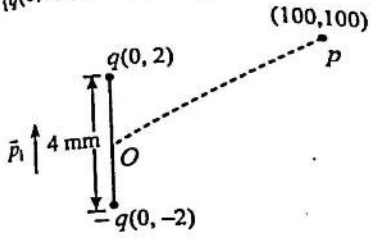
$= \frac{1}{2}\times\frac{C\times 3C}{C+3C}(V^2)$

$= \frac{1}{2}\times\frac{3}{4}CV^2 = \frac{3}{8}CV^2$

$\Delta H = \frac{3}{8}\frac{Q^2}{C}$

JEE-Advanced

1. (b) Case 1: Initial position of dipole {$q(0, 2)$ and $-q\ (0,-2)$}



$\vec{p}_1 = 4q\hat{j}$

$\overrightarrow{OP} = \vec{r} = 100\hat{i} + 100\hat{j}$

$V_{P_1} = \frac{k\vec{p}_1\cdot\vec{r}}{|\vec{r}|^3}$

Potential at P due to dipole

$= \frac{k\{(4q\hat{j})\cdot(100\hat{i} + 100\hat{j})\}}{(100\sqrt{2})^3}$

$Vp_1 = \frac{400kq}{(100\sqrt{2})^3}$ ...(i)

Case 2 : Final position of diode {$q(-1, 2)$ and $-q(1,-2)$}

Potential at P due to dipole

$V_{P_2} = \frac{K.q\left(-2\hat{i} + 4\hat{j}\right)\cdot\left(100\hat{i} + 100\hat{j}\right)}{\left(100\sqrt{2}\right)^3}$

$= \frac{q(200+400)}{\left(100\sqrt{2}\right)^3} = \frac{200q}{\left(100\sqrt{2}\right)^3}$

$\frac{V_{P_1}}{V_{P_2}} = 2 \Rightarrow \frac{V_0}{V_{P_2}} = 2 \Rightarrow V_{P_2} = \frac{V_0}{2}$

2. (b) For $r \in [0, 1]$; $\rho = kr$

For $r \in [1, r_B]$; $\rho = \frac{2k}{r}$

Total charge of the configuration is q

$q = \int_0^1 (kr)4\pi r^2 dr + \int_1^{r_B}\frac{2k}{r}4\pi r^2 dr$

$q = k\pi + 4k\pi\left(r_B^2 - 1\right)$

For $r_B = \sqrt{\frac{3}{2}}$; $q = k\pi + 2k\pi = 3k\pi$

Electric field just outside B is

$E = \frac{1}{4\pi\epsilon_0}\frac{(3\pi k)}{r_B^2} = \frac{k}{2\epsilon_0}$.

For $r_B = \frac{3}{2}$; $q = k\pi + 2\ k\pi = 3\ k\pi$

Electric field just outside B is

$E = \frac{1}{4\pi\epsilon_0}\frac{(3\pi k)}{r_B^2} = \frac{k}{2\epsilon_0}$

For $r_B = \frac{3}{2}$; $q = k\pi + 5\ k\pi = 6\ k\pi$

Potential just outside B is,

$V = \frac{(6\pi k)}{4\pi\epsilon_0\left(\frac{3}{2}\right)} = \frac{k}{\epsilon_0}$

For $r_B = 2$; $q = k\pi + 12\ k\pi = 13\ k\pi$

For $r_B = \frac{5}{2}$; $q = k\pi + 21\ k\pi = 22\ k\pi$

Magnitude of E just outside B is

$\frac{1}{4\pi\epsilon_0}\frac{(22\pi k)}{\left(\frac{25}{4}\right)} = \frac{22}{25}\frac{k}{\epsilon_0}$.

3. (a) $V_0 = \frac{KQ}{R}$ (Potential at surface)

Potential at C

$V_C = \frac{KQ}{R} - \frac{K\alpha Q}{R} = V_0(1-\alpha)$

Potential at B

$V_B = \frac{KQ}{R} - \frac{K(\alpha Q)}{R/2} = V_0(1-2\alpha)$

$\therefore \frac{V_C}{V_B} = \frac{1-\alpha}{1-2\alpha}$

Electric field at A

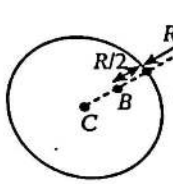
$E_A = \frac{KQ}{(2R)^2} - \frac{K\alpha Q}{R^2} = \frac{KQ}{4R^2} - \frac{\alpha V_0}{R}$

So electric field reduced by $\frac{\alpha V_0}{R}$

Electric field at C

$E_C = \frac{K(\alpha Q)}{R^2} = \frac{\alpha V_0}{R}$

So increased by $\frac{\alpha V_0}{R}$.



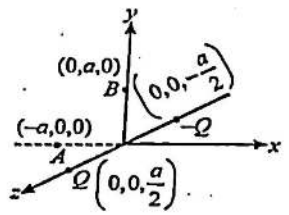
$dq = \frac{Q}{4\pi R^2}dA = Q\alpha$

4. (d) For a thin spherical shell, electric field inside the shell = 0 from gauss law. Electric field outside the shell varies inversely with r^2. Since the electric field inside the shell is zero, the potential inside the shell will be a constant and outside the shell will vary as

@FAKE_CBSE_X@RAJ_EDUNET

$V \propto \frac{1}{r}$. so the graph will be hyperbolic after $r = R$ and before that, it will be a straight line parallel to x axis. Electric field will be zero for $r < R$ and decreasing for $r > R$.
So option d is correct

5. (c)



Point $A(-a,0,0)$ is at a distance $r_A = \frac{\sqrt{5}a}{2}$ from both the charges.
Also, the point $B(-a,0,0)$ is at a distance $r_B = \frac{\sqrt{5}a}{2}$ for a negative charge.

Potential at Point A (V_A): The potential due to each charge at A can be given by $\frac{kq}{r_A}$ for a positive charge and $-\frac{kq}{r_A}$ for a negative charge. If these charges are equal and opposite, and symmetrically located about Point A, the contributions to the potential at A from each charge will cancel out:

$$V_A = \frac{kq}{r_A} - \frac{kq}{r_A} = 0$$

Potential at Point B (V_B): Similarly, the potential at B will be calculated in the same way. Due to symmetry and equal distance r_B, the potentials contributed by the two charges also cancel out:

$$V_B = \frac{kq}{r_B} - \frac{kq}{r_B} = 0$$

Point charge is moved from A to B
$\because V_A = V_B = 0$ or $\Delta V = 0$
$\therefore W = \Delta U = q\Delta V = 0$
or the correct option is (c).

6. (a) There will be an electric field between two cylinders (using Gauss theorem). This electric field will produce a potential difference.

7. (d) Potential at origin will be given by

$$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{x_0} - \frac{1}{2x_0} + \frac{1}{3x_0} - \frac{1}{4x_0} + \ldots\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\cdot\frac{1}{x_0}\left[1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \ldots\right]$$

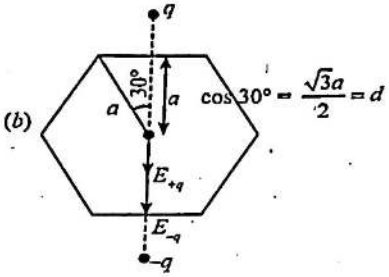
$$= \frac{q}{4\pi\varepsilon_0 x_0}\ln(2)$$

8. (b) Electric potential at any point inside a hollow metallic sphere is constant. Therefore, if potential at surface is 10 V, potential at centre will also be 10 V.

9. (a,b,c)

(a) Due to symmetry $\vec{E_0} = 0$ (calculated using trigonometry)

(b)

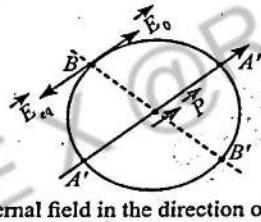


$$E_{net} = \frac{kq}{(2d)^2}\times 2 = \frac{2q\times 4}{4\pi\varepsilon_0\cdot 4\cdot 3a^2} = \frac{q}{6\pi\varepsilon_0 a^2}$$

(c) $V = \frac{7kq}{2d} = \frac{7q}{4\pi\varepsilon_0\cdot\sqrt{3}a} = \frac{7q}{4\sqrt{3}\pi\varepsilon_0 a}$
(Potential at O)

(d) $V = \frac{2kq}{2d} = \frac{2q}{4\pi\varepsilon_0\cdot\sqrt{3}a} = \frac{q}{2\sqrt{3}\pi\varepsilon_0 a}$
(Potential at O)

10. (a, c)



E_0 external field in the direction of $\vec{p} = \frac{p_0}{\sqrt{2}}(\hat{i} + \hat{j})$

B and B' are on equitorial line of dipole. As circle is equipotential, $E_B = 0 \Rightarrow E_{eq} - E_0 = 0$

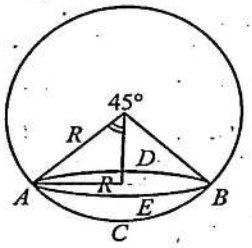
$$E_0 = \frac{KP_0}{R^3}$$

$$\therefore R = \left(\frac{kp_0}{E_0}\right)^{1/3} = \left(\frac{p_0}{4\pi\epsilon_0 E_0}\right)^{1/3}$$

$$\& \ \vec{E}_A = \frac{2k\vec{p}}{R^3} + \vec{E}_0 = 3\vec{E}_0$$

Also $E_B = 0$

11. (a, d) Use angle concept



(a) $\Omega = 2\pi(1 - \cos\theta);\ \theta = 45°$

$$\Rightarrow \phi = \frac{\Omega}{4\pi}\times\frac{Q}{\varepsilon_0} = \frac{-2\pi(1-\cos\theta)}{4\pi}\frac{Q}{\varepsilon_0}$$

$$= \frac{-Q}{2\varepsilon_0}\left(1 - \frac{1}{\sqrt{2}}\right)$$

(b) Total flux due to charge $\phi = \frac{Q}{\varepsilon_0}$

So, ϕ through the curved and flat surface will be less than $\frac{Q}{\varepsilon_0}$

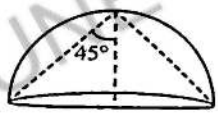
The electric field component normal to the flat surface will diminish.

$$\Rightarrow E = \frac{kQ}{x^2} = \frac{kQ\cos^2\theta}{R^2}$$

$$\Rightarrow E_1 = \frac{kQ\cos^2\theta}{R^2}$$

$\theta \uparrow \cos\theta \downarrow$ So, $E_1 \downarrow$

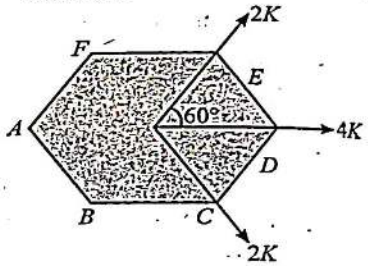
(c) Total flux ϕ due to charge Q is $\frac{Q}{\varepsilon_0}$



So, ϕ through the curved and flat surface will be less than $\frac{Q}{\varepsilon_0}$.

(d) It will be equipotential since the circumference is equidistant from $\frac{kQ}{\sqrt{2}R}$

12. (a, b, c) $E_{along\ the\ line\ BE} = \frac{1}{4\pi\varepsilon_0}\frac{q}{L^2} = 2K$,
similarly
$E_{along\ the\ line\ OD} = 4K$



From the diagram it is clear that the vertical components of the electric fields of magnitude K cancel out and the net horizontal component is :

$E_x = 4K + 2K\cos 60° + 2K\cos 60° = 6K$
(option a is correct)

$$V_O = \frac{1}{4\pi\varepsilon_0}\frac{q}{L} - \frac{1}{4\pi\varepsilon_0}\frac{q}{L} + \frac{1}{4\pi\varepsilon_0}\frac{q}{L}$$

$$- \frac{1}{4\pi\varepsilon_0}\frac{q}{L} + \frac{1}{4\pi\varepsilon_0}\frac{2q}{L} - \frac{1}{4\pi\varepsilon_0}\frac{2q}{L} = 0$$

@MAKE_CBSE_K_@RAJ_EDUNET

Hence Option (*b*) is correct.

Since $E_{(net)}$ is in the direction of OD, the potential at all points perpendicular to this line will be constant.

So line PR is equipotential Hence option (*c*) is correct

Line ST is along the line OD so the potential will decrease along the line ST

Hence option *d* is incorrect.

13. (*c, d*)

(*a*) Gauss's law is valid only when $E \propto r^{-2}$

(*b*) Gauss's law cannot be used to calculate the field distribution around an electric dipole.

(*c*) is correct as between two point charges we will get a point where the electric field due to the two point charges cancel out each other. If two point charges are of opposite sign then the two fields are along the same direction hence they cannot be zero.

(*d*) $W_{AB} = q(\Delta V) = 1(V_B - V_A)$

or, $W_{AB} = V_B - V_A$

14. (*c, d*) If charges are of opposite signs then the two fields are along the same direction. So, they cannot be zero. Hence, the charges should be of same sign.

Therefore, option (*c*) is correct.

Further, Work done by external force = change in potential energy

$\therefore\ W_{A\to B} = q(\Delta V) = (+1)(V_B - V_A)$

or $W_{A\to B} = V_B - V_A$

Therefore, option (*d*) is also correct.

$\therefore$ Correct options are (*c*) and (*d*).

NOTE For option (*a*), students are advised to see the proof of Gauss theorem.

15. (*a, b, c, d*) Inside a conducting shell electric field is always zero. Therefore, option (*a*) is correct. When the two are connected, their potentials become the same.

$\therefore\ V_A = V_B$

or $\dfrac{Q_A}{R_A} = \dfrac{Q_B}{R_B}$ $\left(V = \dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{R}\right)$

Since, $R_A > R_B$

$\therefore\ Q_A > Q_B$

$\therefore$ Option (*b*) is correct.

Potential is also equal to, $V = \dfrac{\sigma R}{\varepsilon_0}$, $V_A = V_B$

$\therefore\ \sigma_A R_A = \sigma_B R_B$

or $\dfrac{\sigma_A}{\sigma_B} = \dfrac{R_B}{R_A}$ or $\sigma_A < \sigma_B$

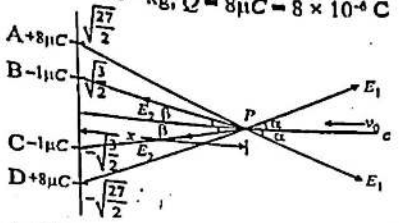
$\therefore$ Option (*c*) is correct.

Electric field on surface, $E = \dfrac{\sigma}{\varepsilon_0}$ or $E \propto \sigma$

Since, $\sigma_A < \sigma_B \therefore E_A < E_B$

$\therefore$ Option (*d*) is also correct.

16. $q = 1\mu C = 10^{-6}$ C, $q_0 = 0.1\ \mu C = 10^{-7}$ C, $m = 6.4 \times 10^{-4}$ kg, $Q = 8\mu C = 8 \times 10^{-6}$ C



Let P be any point at a distance x from origin, then

$AP = CP$

$BP = DP$

Electric potential at P will be

$V = \dfrac{2kQ}{BP} - \dfrac{2kq}{AP}$

where $k = \dfrac{1}{4\pi\varepsilon_0}$

$V = 2k\left[\dfrac{Q}{\sqrt{\frac{27}{2} + x^2}} - \dfrac{q}{\sqrt{\frac{3}{2} + x^2}}\right]$

$V = 2 \times 9 \times 10^9 \times 10^{-6}\left[\dfrac{8}{\sqrt{\frac{27}{2} + x^2}} - \dfrac{1}{\sqrt{\frac{3}{2} + x^2}}\right]$

Electric field at P is

$E = -\dfrac{dV}{dx}$

$E = 1.8 \times 10^4 \times \left[\dfrac{8}{\sqrt{\frac{27}{2} + x^2}} - \dfrac{1}{\sqrt{\frac{3}{2} + x^2}}\right]$

At $E = 0$

$x = \sqrt{\dfrac{5}{2}}, -\sqrt{\dfrac{5}{2}}$

The minimum value of kinetic energy of the particle at infinity should be enough to take the particle upto

$x = +\sqrt{\dfrac{5}{2}}$

Because at $x = +\sqrt{\dfrac{5}{2}}$, $E = 0$

Electrostatic force on q_0 is zero

for $x > \sqrt{\dfrac{5}{2}}$, E is repulsive (towards + *ve* x-axis)

for $x < \sqrt{\dfrac{5}{2}}$, E is attractive (towards −*ve* x-axis)

Now, potential at $\sqrt{\dfrac{5}{2}}$ m is

$V = 1.8 \times 10^4\left[\dfrac{8}{\sqrt{\frac{27}{2} + \frac{5}{2}}} - \dfrac{5/2}{\sqrt{\frac{3}{2} + \frac{5}{2}}}\right]$

$V = 1.8 \times 10^4 \times \dfrac{3}{2}$

$V = 2.7 \times 10^4$ V

Applying energy conservation at $x = \infty$ and $x = \sqrt{\dfrac{5}{2}}$ m

$\dfrac{1}{2}mv_0^2 = q_0 V$

$v_0 = \sqrt{\dfrac{2q_0 V}{m}}$

$v_0 = \sqrt{\dfrac{2 \times 10^{-7} \times 2.7 \times 10^4}{6 \times 10^{-4}}} = 3$ m/s

Potential at origin is

$V_0 = 1.8 \times 10^4\left[\dfrac{8}{\left(\frac{27}{2}\right)^{\frac{1}{2}}} - \dfrac{1}{\left(\frac{3}{2}\right)^{\frac{1}{2}}}\right]$

$V_0 = \sqrt{6} \times 10^4 \approx 2.44 \times 10^4$

Let T be the kinetic energy of the particle at origin.

Applying energy conservation at $x = 0$ and at $x = \infty$

$T = q_0 V - 0 = \dfrac{m^2}{V_0}$

$T = \dfrac{1}{2}mV_0^2 - q_0 V_0$

$T = \dfrac{1}{2} \times 6 \times 10^{-4} \times (3)^2 - 2.44 \times 10^4 \times 10^{-7}$

$T = 27 \times 10^{-4} - 2.44 \times 10^{-4}$

$T = 2.6 \times 10^{-4}$ J

17. (*a*) Net torque on $(-q)$ about a point (say P) lying over $+Q$ is zero. Therefore, angular momentum of $(-q)$ about point P should remain constant.

18. (*a,b,c,d*) The given graph is of charged conducting sphere of radius R_0. The whole charge q is distributed on the surface of the sphere.

19. (*c, d*) Under electrostatic conditions, all points lying on the conductor are at same potential. Therefore, potential at A = potential at B. Hence, option (*c*) is correct. From Gauss theorem, total flux through the surface of the cavity will be q/ε_0.

NOTE Instead of an elliptical cavity, if it would have been a spherical cavity then options (*a*) and (*b*) were also correct.

@MKE_CBSE_GRAJ_EDUNET

20. (*d*) Balls will gain positive charge and hence move towards negative plate. On reaching negative plate, balls will attain negative charge and come back to positive plate. So, balls will keep on oscillating. But oscillation is not SHM, as force on balls is not $\propto x$.
$\therefore$ (*d*) is correct.

21. (*a*) As the balls keep on carrying charge from one plate to another, current will keep on flowing. At bottom plate

$$\frac{kq}{r} = V_0 \qquad \left(\therefore k = \frac{1}{4\pi\varepsilon_0}\right)$$

$$\Rightarrow q = \frac{V_0 r}{k}$$

Inside the cylinder, electric field $E = [V_0 - (-V_0)]h = 2V_0 h$.
$\Rightarrow$ Acceleration of each ball,

$$a = \frac{qE}{m} = \frac{2hr}{km} \cdot V_0^2$$

$\Rightarrow$ Time taken by the balls to reach the other plate,

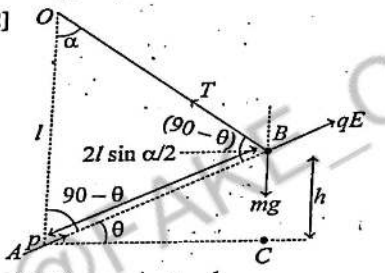
$$t = \sqrt{\frac{2h}{a}} = \sqrt{\frac{2h \cdot km}{2hrV_0^2}} = \frac{1}{V_0}\sqrt{\frac{km}{r}}$$

If there are n balls, then
Average current,

$$i_{av} = \frac{nq}{t} = n \times \frac{V_0 r}{k} \times V_0 \sqrt{\frac{r}{km}}$$

$$\Rightarrow i_{av} \propto V_0^2$$

22. [2]



$$U_i = 0$$

$$U_f = \frac{kqp}{\left(2l\sin\frac{\alpha}{2}\right)^2} + mgh \qquad \ldots(i)$$

Now, from ΔOAB,

$$\alpha + 90 - \theta + 90 - \theta = 180$$

$$\Rightarrow \alpha = 2\theta$$

From ΔABC, $h = 2l\sin\left(\frac{\alpha}{2}\right)\sin\theta$

$$h = 2l\sin\left(\frac{\alpha}{2}\right)\sin\left(\frac{\alpha}{2}\right)$$

$$\Rightarrow h = 2l\sin^2\left(\frac{\alpha}{2}\right)$$

Now, charge is in equilibrium at point B.
So, using sine rule,

$$\frac{mg}{\sin\left(90+\frac{\alpha}{2}\right)} = \frac{qE}{\sin(180-20)}$$

$$\Rightarrow \frac{mg}{\cos\frac{\alpha}{2}} = \frac{qE}{\sin 20} \Rightarrow \frac{mg}{\cos\frac{\alpha}{2}} = \frac{qE}{\cos\frac{\alpha}{2}}$$

$$\Rightarrow \frac{mg}{\cos\frac{\alpha}{2}} = \frac{qE}{2\sin\frac{\alpha}{2}\cos\frac{\alpha}{2}}$$

$$\Rightarrow qE = 2mg\sin\left(\frac{\alpha}{2}\right)$$

$$\Rightarrow \frac{q2kp}{\left(2l\sin\frac{\alpha}{2}\right)^3} = mg2\sin\left(\frac{\alpha}{2}\right)$$

$$\Rightarrow \frac{kpq}{\left(2l\sin\frac{\alpha}{2}\right)^2}$$

$$= mg\sin\left(\frac{\alpha}{2}\right) \times \left(2l\sin\frac{\alpha}{2}\right)$$

$$\Rightarrow \frac{kpq}{\left(2l\sin\frac{\alpha}{2}\right)^2} = mgh\left(\frac{\alpha}{2}\right)$$

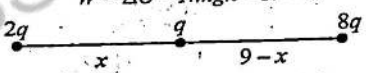
Substituting this in Eq. (*i*), we get

$$U_f = mgh + \frac{kpq}{\left(2l\sin\frac{\alpha}{2}\right)^2}$$

$$\Rightarrow U_f = 2mgh$$

$$W = \Delta U = Nmgh = N = 2$$

23.



For potential energy to be minimum the bigger charges should be farthest. Let x be the distance of q from $2q$. Then potential energy of the system shown in the figure would be

$$U = K\left[\frac{(2q)(q)}{x} + \frac{(8q)(q)}{(9-x)} + \frac{(2q)(8q)}{9}\right]$$

Here, $K = \frac{1}{4\pi\varepsilon_0}$

For U to be minimum $\frac{2}{x} + \frac{8}{9-x}$ should be minimum.

$$\frac{d}{dx}\left[\frac{2}{x} + \frac{8}{9-x}\right] = 0$$

$$\therefore \frac{-2}{x^2} + \frac{8}{(9-x)^2} = 0$$

$$\therefore \frac{x}{9-x} = \frac{1}{2} \text{ or } x = 3 \text{ cm}$$

i.e. distance of charge q from $2q$ should be 3 cm.
Electric field at q

$$E = \frac{K(2q)}{(3\times10^{-2})^2} - \frac{K(8q)}{(6\times10^{-2})^2} = 0$$

24. [8.48] Equating the energy of $(-q)$ at C and D

$$K_C + U_C = K_D + U_D \qquad \ldots(i)$$

Here, $K_C = 4$ J

$$U_C = 2\left[\frac{1}{4\pi\varepsilon_0}\frac{(q)(-q)}{AC}\right]$$

$$= \frac{-2\times9\times10^9\times(5\times10^{-5})^2}{5} = -9\text{ J}$$

$$K_D = 0$$

and $U_D = 2\left[\frac{1}{4\pi\varepsilon_0}\frac{(q)(-q)}{AD}\right]$

$$= \frac{-2\times9\times10^9\times(5\times10^{-5})^2}{AD} = -\frac{45}{AD}$$

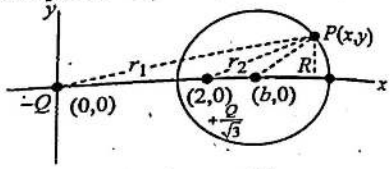
Substituting these values in Eq. (*i*)

$$4 - 9 = 0 - \frac{45}{AD} \quad \therefore AD = 9\text{ m}$$

$$\therefore OD = \sqrt{AD^2 - OA^2} = \sqrt{(9)^2 - (3)^2}$$

$$= \sqrt{81-9} = 8.48\text{ m}$$

25. Let point P on circle



$$V_p = 0 = \frac{k(-Q)}{r_1} + \frac{kQ/\sqrt{3}}{r_2}$$

$$\frac{kQ}{r_1} = \frac{kQ/\sqrt{3}}{r_2}$$

$$\frac{1}{\sqrt{x^2+y^2}} = \frac{1}{\sqrt{3}\sqrt{(x-2)^2+y^2}}$$

$$3(x-2)^2 + 3y^2 = x^2 + y^2$$

$$3(x^2 + 4 - 4x) - x^2 + 2y^2 = 0$$

$$2x^2 + 12 - 12x + 2y^2 = 0$$

$$x^2 + 6 - 6x + y^2 = 0$$

$$(x-3)^2 + y^2 = \left(\sqrt{3}\right)^2$$

$$R = \sqrt{3} = 1.73$$

$$b = 3$$

26. Electric field is constant. Therefore, electrostatic force $q\mathbf{E}$ is also constant.
Hence, $W_{Fe} = \mathbf{F} \cdot \mathbf{d}$ (d = displacement)

$$= (qE\hat{i}) \cdot [r_s - r_p]$$

$$= qE\hat{i} \cdot [(-a\hat{i} - b\hat{j})] = -qEa$$

@IAKE_CBSE_X@RAJEDUNET

27. Magnitude of electric field is greatest at a point B where electric lines of force are most close to each other.

28. [True] Mass of negatively charged sphere will be slightly more than the mass of positively charged sphere because some electrons will be given to the negatively charged sphere while some electrons will be taken out from the positively charged sphere.

29. [True]

30. Let q be the charge on the bubble, then

$$V = \frac{Kq}{a} \qquad \left(\text{Here, } K = \frac{1}{4\pi\varepsilon_0}\right)$$

$$q = \frac{Va}{K}$$

Let after collapsing, the radius of droplet becomes R, then equating the volume, we have $(4\pi a^2)t = \frac{4}{3}\pi R^3$

$$\therefore R = (3a^2t)^{1/3}$$

Now, potential of droplet will be $V' = \frac{Kq}{R}$

Substituting the values, we have

$$V' = \frac{(K)\left(\frac{Va}{K}\right)}{(3a^2t)^{1/3}} \text{ or } V' = V\left(\frac{a}{3t}\right)^{1/3}$$

31. Electric field near a large metallic plate is given by $E = \sigma/\varepsilon_0$. In between the plates the two fields will be in opposite directions. Hence,

$$E_{net} = \frac{\sigma_1 - \sigma_2}{\varepsilon_0} = E_0 \text{ (say)}$$

Now, $W = (q)$ (potential difference)

$$= q\,(E_0\, a\cos 45°)$$

$$= (q)\left(\frac{\sigma_1 - \sigma_2}{\varepsilon_0}\right)\left(\frac{a}{\sqrt{2}}\right) = \frac{(\sigma_1 - \sigma_2)qa}{\sqrt{2}\varepsilon_0}$$

32. (a) Applying energy conservation principle, increase in kinetic energy of the dipole = decrease in electrostatic potential energy of the dipole.

$\therefore$ Kinetic energy of dipole at distance d from origin

$= U - U_f$

or $KE = 0 - (-p\cdot E) = p\cdot E$

$$= (p\hat{i})\cdot\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{d^2}\hat{i}\right) = \frac{qp}{4\pi\varepsilon_0 d^2}$$

(b) Electric field at origin due to the dipole,

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{d^3}\hat{i} \qquad (E_{axis} \uparrow\uparrow p)$$

$\therefore$ Force on charge q

$$F = qE = \frac{pq}{2\pi\varepsilon_0 d^3}\hat{i}$$

33. For potential energy of the system of charges, total number of charge pairs will be ${}^8C_2$ or 28. Of these 28 pairs, 12 unlike charges are at a separation a, 12 like charges are at separation $\sqrt{2}\,a$ and 4 unlike charges are at separation $\sqrt{3}\,a$. Therefore, the potential energy of the system is given as

$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{(12)(q)(-q)}{a} + \frac{(12)(q)(q)}{\sqrt{2}a} + \frac{(4)(q)(-q)}{\sqrt{3}a}\right]$$

$$= -5.824\left(\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{a}\right)$$

The binding energy of this system is therefore,

$$|U| = 5.824\left(\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{a}\right)$$

So, work done by external forces in disassembling, this system of charges is

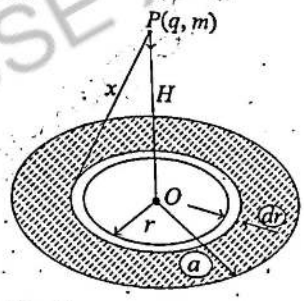
$$W = 5.824\left(\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{a}\right)$$

Alternate solution:

$$W = \Delta U = U_f - U_i = -U_i \qquad (\text{as } U_f = 0)$$

34. Potential at a height H on the axis of the disc $V(P)$

The charge dq contained in the ring shown in figure



$$dq = (2\pi r dr)\sigma$$

Potential at P due to this ring

$$dV = \frac{1}{4\pi\varepsilon_0}\cdot\frac{dq}{x} \text{ where } x = \sqrt{H^2 + r^2}$$

$$dV = \frac{1}{4\pi\varepsilon_0}\cdot\frac{dq}{x} \text{ where } x = \sqrt{H^2 + r^2}$$

$$dV = \frac{1}{4\pi\varepsilon_0}\cdot\frac{(2\pi r dr)\sigma}{\sqrt{H^2 + r^2}}$$

$$= \frac{\sigma}{2\varepsilon_0}\frac{rdr}{\sqrt{H^2 + r^2}}$$

$\therefore$ Potential due to the complete disc

$$V_p = \int_{r=0}^{r=a} dV = \frac{\sigma}{2\varepsilon_0}\int_{r=0}^{r=a}\frac{rdr}{\sqrt{H^2 + r^2}}$$

$$V_p = \frac{\sigma}{2\varepsilon_0}\left[\sqrt{a^2 + H^2} - H\right]$$

Potential at centre, (O) will be

$$V_o = \frac{\sigma a}{2\varepsilon_0} \qquad (H = 0)$$

(a) Particle is released from P and it just reaches point O. Therefore, from conservation of mechanical energy

Decrease in gravitational potential energy = Increase in electrostatic potential energy

($\Delta KE = 0$ because $K_i = K_f = 0$)

$\therefore mgH = q[V_O - V_P]$

or $gH = \left(\frac{q}{m}\right)\left(\frac{\sigma}{2\varepsilon_0}\right)$

$$[a - \sqrt{a^2 + H^2} + H] \quad ...(i)$$

$$\frac{q}{m} = \frac{4\varepsilon_0 g}{\sigma} \quad \therefore \quad \frac{q\sigma}{2\varepsilon_0 m} = 2g$$

Substituting in Eq. (i), we get

$$gH = 2g\,[a + H - \sqrt{a^2 + H^2}\,]$$

or $\frac{H}{2} = (a + H) - \sqrt{a^2 + H^2}$

or $\sqrt{a^2 + H^2} = a = \frac{H}{2}$

$$a^2 + H^2 = a^2 + \frac{H^2}{4} + aH$$

or $\frac{3}{4}H^2 = aH \Rightarrow H = \frac{4}{3}a$

and $H = 0$

$\therefore H = (4/3)a$

(b) Potential energy of the particle at height H = Electrostatic potential energy + gravitational potential energy

$\therefore U = qV + mgH$

Here V = Potential at height H

$$U = \frac{\sigma q}{2\varepsilon_0}\left[\sqrt{a^2 + H^2} - H\right] + mgH \quad ...(ii)$$

At equilibrium position $F = \frac{-dU}{dH} = 0$

Differentiating Eq. (ii) w.r.t. H

or $mg + \sigma\frac{q}{2\varepsilon_0}$

$$\left[\left(\frac{1}{2}\right)(2H)\frac{1}{\sqrt{a^2 + H^2}} - 1\right] = 0$$

$$\left(\because \frac{\sigma q}{2\varepsilon_0} = 2mg\right)$$

@TAKE_CBSE_X@RAJ_EDUNET

$$\therefore \quad mg + 2mg\left[\frac{H}{\sqrt{a^2+H^2}} - 1\right] = 0$$

$$\text{or} \quad 1 + \frac{2H}{\sqrt{a^2+H^2}} - 2 = 0$$

$$\text{or} \quad \frac{2H}{\sqrt{a^2+H^2}} = 1 \quad \text{or} \quad \frac{H^2}{a^2+H^2} = \frac{1}{4}$$

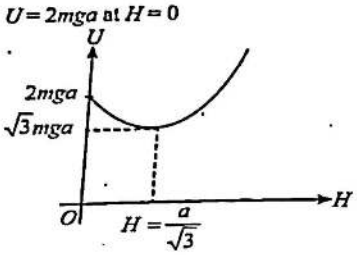
$$\text{or} \quad 3H^2 = a^2 \text{ or } H = \frac{a}{\sqrt{3}}$$

From Eq. (*ii*), we can write $U - H$ equation as

$$U = mg(2\sqrt{a^2+H^2} - H)$$

(Parabolic variation)

$U = 2mga$ at $H = 0$



and $U = U_{min} = \sqrt{3}\, mga$ at $H = \frac{a}{\sqrt{3}}$

Therefore, $U - H$ graph will be as shown

Note that at $H = \frac{a}{\sqrt{3}}$, U is minimum.

Therefore, $H = \frac{a}{\sqrt{3}}$ is stable equilibrium position.

35. Let q_1 and q_2 be the charges on the two spheres before connecting them.

Then, $q_1 = \sigma(4\pi R^2)$,

and $q_2 = \sigma(4\pi)(2R)^2 = 16\,\sigma\pi R^2$

Therefore, total charge (q) on both the spheres is

$q = q_1 + q_2 = 20\,\sigma\pi R^2$

Now, after connecting, the charge is distributed in the ratio of their capacities, which in turn depends on the ratio of their radii ($C = 4\pi\varepsilon_0 R$).

$$\therefore \quad \frac{q_1'}{q_2'} = \frac{R}{2R} = \frac{1}{2}$$

$$\therefore \quad q_1' = \frac{q}{3} = \frac{20}{3}\sigma\pi R^2$$

$$\text{and } q_2' = \frac{2q}{3} = \frac{40}{3}\sigma\pi R^2$$

Therefore, surface charge densities on the spheres are

$$\sigma_1 = \frac{q_1'}{4\pi R^2} = \frac{(20/3)\sigma\pi R^2}{4\pi R^2} = \frac{5}{3}\sigma$$

$$\text{and } \sigma_2 = \frac{q_2'}{4\pi(2R)^2} = \frac{(40/3)\sigma\pi R^2}{16\pi R^2} = \frac{5}{6}\sigma$$

Hence, surface charge density on the bigger sphere is σ_2 i.e. $(5/6)\sigma$.

36. Total charge in the ring is $Q = (2\pi R)\lambda$

Potential due to a ring at a distance of x from its centre on its axis is given by

$$V(x) = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{\sqrt{R^2+x^2}}$$

and at the centre is $V_{centre} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$

Using the above formula

$$V_P = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2\pi R\lambda}{\sqrt{R^2+3R^2}} = \frac{\lambda}{4\varepsilon_0}$$

$$V_o = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2\pi R\lambda}{R} = \frac{\lambda}{2\varepsilon_0}$$

$V_o > V_P$

Potential difference between points O and P is

$$V = V_o - V_P = \frac{\lambda}{2\varepsilon_0} - \frac{\lambda}{4\varepsilon_0} = \frac{\lambda}{4\varepsilon_0}$$

$$\therefore \quad \frac{1}{2}mv^2 \geq qV \text{ or } v \geq \sqrt{\frac{2qV}{m}}$$

$$\text{or} \quad v \geq \sqrt{\frac{2q\lambda}{4\varepsilon_0 m}} \text{ or } v \geq \sqrt{\frac{q\lambda}{2\varepsilon_0 m}}$$

Therefore, minimum value of speed v should be $v_{min} = \sqrt{\frac{q\lambda}{2\varepsilon_0 m}}$

37. (*a*) In this case the electric field exists from centre of the sphere to infinity. Potential energy is stored in electric field, with energy density

$$u = \frac{1}{2}\varepsilon_0 E^2 \qquad (\because \text{Energy/Volume})$$

(*i*) Energy stored within the sphere (U_1)

Electric field at a distance r is

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{R^3}\cdot r$$

$$u = \frac{1}{2}\varepsilon_0 E^2 = \frac{\varepsilon_0}{2}\left\{\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{R^3}r\right\}^2$$

Volume of element,

$dV = (4\pi r^2)dr$

Energy stored in this volume, $dU = u\,(dV)$

$$dU = (4\pi r^2 dr)\frac{\varepsilon_0}{2}\cdot\left\{\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{R^3}r\right\}^2$$

$$dU = \frac{1}{8\pi\varepsilon_0}\cdot\frac{Q^2}{R^6}\cdot r^4 dr$$

$$\therefore \quad U_1 = \int_0^R dU = \frac{1}{8\pi\varepsilon_0}\frac{Q^2}{R^6}\int_0^R r^4 dr$$

$$= \frac{Q^2}{40\pi\varepsilon_0 R^6}[r^5]_0^R$$

$$U_1 = \frac{1}{40\pi\varepsilon_0}\cdot\frac{Q^2}{R} \qquad \ldots(i)$$

(*ii*) Energy stored outside the sphere (U_2)

Electric field at a distance r is

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r^2}$$

$$\therefore \quad u = \frac{1}{2}\varepsilon_0 E^2 = \frac{\varepsilon_0}{2}\left\{\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r^2}\right\}^2$$

$dU = (4\pi r^2 dr)$

$$\therefore \quad dU = u\cdot dV$$

$$= (4\pi r^2 dr)\left[\frac{\varepsilon_0}{2}\left(\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r^2}\right)^2\right]$$

$$dU = \frac{Q^2}{8\pi\varepsilon_0}\frac{dr}{r^2}$$

$$\therefore \quad U_2 = \int_R^\infty dU = \frac{Q^2}{8\pi\varepsilon_0}\cdot\int_R^\infty\frac{dr}{r^2}$$

$$U_2 = \frac{Q^2}{8\pi\varepsilon_0 R} \qquad \ldots(ii)$$

Therefore, total energy of the system is

$$U = U_1 + U_2 = \frac{Q^2}{40\pi\varepsilon_0 R} + \frac{Q^2}{8\pi\varepsilon_0 R}$$

$$\text{or} \quad U = \frac{3Q^2}{20\pi\varepsilon_0 R}$$

(*b*) Comparing this with gravitational forces, the gravitational potential energy of earth will be

$$U = -\frac{3}{5}\frac{GM^2}{R}$$

by replacing Q^2 by M^2 and $\frac{1}{4\pi\varepsilon_0}$ by G

$$g = \frac{GM}{R^2}$$

$$\therefore \quad G = \frac{gR^2}{M}$$

$$\therefore \quad U = \frac{-3}{5}MgR$$

© FAKE_CBSE_X_CRAJ_EDUNET

Therefore, energy needed to completely disassemble the earth against gravitational pull amongst its constituent particles will be given by

$E = |U| = \frac{3}{5} MgR$

Substituting the values, we get

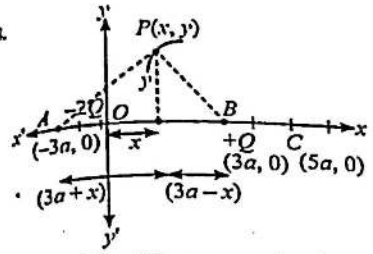
$E = \frac{3}{5}$ (10 m/s²) (2.5 × 10¹¹ kg-m)

$E = 1.5 \times 10^{12}$ J

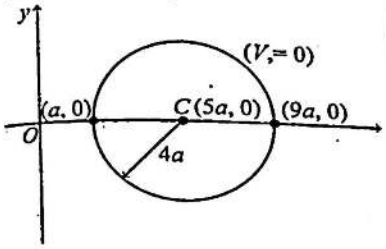
(c) This is the case of a charged spherical conductor of radius R, energy of which is given by $= \frac{1}{2}\frac{Q^2}{C}$

or $U = \frac{1}{2} \cdot \frac{Q^2}{4\pi\varepsilon_0 R}$ or $U = \frac{Q^2}{8\pi\varepsilon_0 R}$

18.



(a) Let P(x, y) be a general point on x-y plane. Electric potential at point P would be,



V = (potential due to Q) + (potential due to $-2Q$)

or $V = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q}{\sqrt{(3a-x)^2+y^2}}\right]$

$+\frac{1}{4\pi\varepsilon_0}\left[\frac{-2Q}{\sqrt{(3a-x)^2+y^2}}\right]$ ...(i)

Given $V = 0$

$\therefore 4[(3a-x)^2 + y^2] = (3a+x)^2 + y^2$

On simplifying, we get $(x - 5a)^2 + y = (4a)^2$

This is the equation of a circle of radius $4a$ and centre at $(5a, 0)$.

(b) On x-axis, potential will be undefined (or say $\pm\infty$) at $x = 3a$ and $x = -3a$, because charge Q and $-2Q$ are placed at these two points.

So, between $-3a < x < 3a$ we can find potential by putting $y = 0$ in Eq. (i). Therefore,

$V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{3a-x} - \frac{2}{3a+x}\right]$

for $-3a < x < 3a$

$V = 0$ at $x = a$

$V \to -\infty$ at $x \to -3a$

and $V \to +\infty$ at $x \to 3a$

For $x > 3a$, there is again a point where potential will become zero so for $x > 3a$, we can write

$V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{x-3a} - \frac{2}{3a+x}\right]$ for $x > 3a$

$V = 0$ at $x = 9a$

For $x < -3a$, we can write

$V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{3a-x} - \frac{2}{-3a-x}\right]$

for $x < -3a$

In this region potential will be zero only at $x \to -\infty$

Thus, we can summarise it as under.

(i) At $x = 3a, V = +\infty$

(ii) At $x = -3a, V = -\infty$

(iii) For $x < -3a$

$V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{3a-x} - \frac{2}{-3a-x}\right]$

(iv) For $-3a < x < 3a$, expression of V is same i.e.

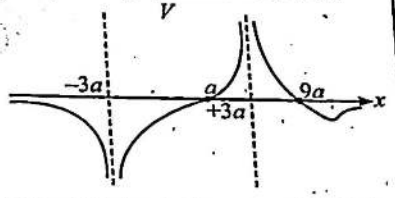
$= \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{3a-x} - \frac{2}{3a+x}\right]$

(v) For $x > 3a$,

$V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{x-3a} - \frac{2}{3a+x}\right]$

Potential on x-axis is zero at two places at $x = a$ and $x = 9a$.

The V-x graph is shown below,



(c) Potential at centre i.e. at $x = 5a$ will be,

$V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{2a} - \frac{2}{8a}\right] = \frac{Q}{16\pi\varepsilon_0 a}$

= positive

Potential on the circle will be zero.

Since, potential at centre > potential on circumference on it, the particle will cross the circle because positive charge moves from higher potential to lower potential.

Speed of particle, while crossing the circle would be,

$v = \sqrt{\frac{2q(\Delta V)}{m}} = \sqrt{\frac{Qq}{8\pi\varepsilon_0 ma}}$

Here, ΔV is the potential difference between the centre and circumference of the circle.

39. Before opening the switch potential difference across both the capacitors is V, as they are in parallel. Hence, energy stored in them is,

$U_A = U_B = \frac{1}{2}CV^2$

$\therefore U_{Total} = CV^2 = U_i$ ...(i)

After opening the switch, potential difference across A is V and its capacity is $3C$.

$\therefore U_A = \frac{1}{2}(3C)V^2 = \frac{3}{2}CV^2$

In case of capacitor B, charge stored in it is $q = CV$ and its capacity is also $3C$.

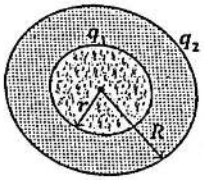
Therefore, $U_B = \frac{q^2}{2(3C)} = \frac{CV^2}{6}$

$\therefore U_{Total} = \frac{3CV^2}{2} + \frac{CV^2}{6} = \frac{10}{6}CV^2$

$= \frac{5CV^2}{3} = U_f$ (ii)

From Eqs. (i) and (ii), we get $\frac{U_i}{U_f} = \frac{3}{5}$

40. Let q_1 and q_2 be the charges on them.



$\sigma_1 = \sigma_2$

$\therefore \frac{q_1}{4\pi r^2} = \frac{q_2}{4\pi R^2} \Rightarrow \frac{q_1}{q_2} = \frac{r^2}{R^2}$

i.e., charge on them is distributed in above ratio.

or $q_1 = \frac{r^2}{r^2+R^2}Q$ and $q_2 = \frac{R^2}{r^2+R^2}Q$

Potential at centre V = potential due to q_1 + potential due to q_2

or $V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1}{r} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_2}{R}$

$= \frac{Q(R+r)}{4\pi\varepsilon_0(r^2+R^2)}$

41. (c) X is nearly 1×10^{-9} V

Explanation:- here, the force on charge(proton) i.e; qE is equal to the force due to its mass.

@FAKE_CBSE_X @RAJ_EDUNET

$qE = mg$ and $E = \frac{V}{d}$

so, $q\frac{V}{d} = mg$

$V = \frac{mgd}{q}$

putting all the values,

$V = \frac{1.67\times10^{-27}\times9.8\times10^{-2}}{1.6\times10^{-19}} \approx 1\times10^{-9}V$

Final Answer:- Option *c* is the correct answer.

42. *(a)* $-\int_{l=\infty}^{l=0} E\cdot dl = \int_{l=\infty}^{l=0} dV = V$

(centre) $-V$ (infinity) but V (infinity) $= 0$

$\therefore -\int_{l=\infty}^{l=0} E\cdot dl$ corresponds to potential at centre of ring.

and $V(\text{centre}) = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{R}$

$= \frac{(9\times10^9)(1.11\times10^{-10})}{0.5} \approx 2V$

43. [6] $E = \frac{V}{d} = \frac{200}{0.01} = 2\times10^4$ V/m

When terminal velocity is achieved

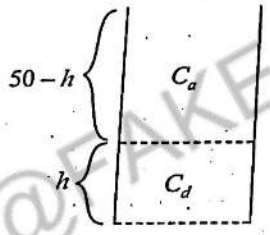
$qE = mg$

$\Rightarrow n\times1.6\times10^{-19}\times2\times10^4$

$= \frac{4\pi}{3}(8\times10^{-7})^3\times900\times10 \Rightarrow n \approx 6$

44. *(b)* Volume of liquid in 10s, $V = 2500$cc

$h = \frac{\text{Volume}}{\text{Area}} = \frac{2500}{50\times5} = 10$ cm



Capacitance in dielectric

$C_d = \frac{A_d\varepsilon_0 k}{d}$

$= \frac{50\times10^{-2}\times10\times10^{-2}\varepsilon_0\times3}{5\times10^{-2}} = 3\varepsilon_0$

Capacitance in air,

$C_a = \frac{A_a\varepsilon_0}{d}$

$= \frac{50\times10^{-2}\times(50\times10)\times10^{-2}\varepsilon_0}{5\times10^{-2}} = 4\varepsilon_0$

Net capacitance

$C = C_a + C_d = 7\varepsilon_0 = 7\times9\times10^{-12} = 63pF$

45. *(c)* For sphere 1,

Using Gauss's law, $E_1\times4\pi R^2 = \frac{Q}{\varepsilon_0}$

$\Rightarrow E_1 = \frac{Q}{4\pi R^2\varepsilon_0}$

For sphere 2,

$E_2\times4\pi R^2 = \frac{2Q}{\varepsilon_0} \Rightarrow E_2 = \frac{2Q}{4\pi R^2\varepsilon_0}$

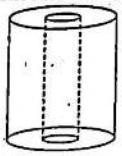
For sphere 3, $E_3\times4\pi R^2 = \frac{\rho\frac{4}{3}\pi R^3}{\varepsilon_0}$

Also, $4Q = \frac{4}{3}\pi(2R)^3$

$\Rightarrow E_3\times4\pi R^2 = \frac{Q/2}{\varepsilon_0} \Rightarrow E_2 = \frac{Q/2}{4\pi R^2\varepsilon_0}$

Therefore $E_2 > E_1 > E_3$

46. *(c)* The magnitude of electric field at a distance r from the axis is given as:

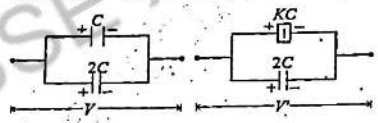


$E = \frac{\lambda}{2\pi\varepsilon_0 r}$ *i.e.* $E \propto \frac{1}{r}$

Here, λ is the charge per unit length of the capacitor.

47. Total charge will remain unchanged.

Hence, $Q = Q'$ or $3CV = (KC + 2C)V'$



$\therefore V' = \left(\frac{3}{K+2}\right)V$

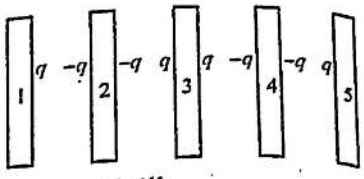
48. In the circuit shown in figure, there is a capacitor between plates 1 and 2, the capacity of which is : $C_1 = \frac{\varepsilon_0 A}{d}$ and potential difference between its plates is V. Therefore, charge stored in it is, $q = C_1V = \frac{\varepsilon_0 AV}{d}$

Since, plate 1 is connected with positive terminal, hence this charge q will be positive. Plate 4 is making two capacitors, one with 3 and other with 5.

Hence, charge on it will be $-2q$ or $\frac{-2\varepsilon_0 AV}{d}$

Charge on it is negative because this is connected with negative plate.

Charges on both sides of the plates are shown below.

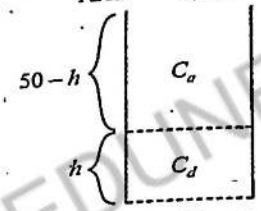


Here, $q = \frac{\varepsilon_0 AV}{d}$

49. [True] Electric field between the plates of capacitor is almost uniform. Therefore, force on both the protons will be identical. It hardly matters whether they are placed near positive plate or negative plate.

50. [63] Volume of liquid in 10s, $V = 2500$cc

$h = \frac{\text{Volume}}{\text{Area}} = \frac{2500}{50\times5} = 10$ cm



Capacitance in dielectric

$C_d = \frac{A_d\varepsilon_0 k}{d}$

$= \frac{50\times10^{-2}\times10\times10^{-2}\varepsilon_0\times3}{5\times10^{-2}} = 3\varepsilon_0$

Capacitance in air,

$C_a = \frac{A_a\varepsilon_0}{d}$

$= \frac{50\times10^{-2}\times(50-10)\times10^{-2}\varepsilon_0}{5\times10^{-2}} = 4\varepsilon_0$

Net capacitance

$C = C_a + C_d = 7\varepsilon_0 = 7\times9\times10^{-12} = 63$pF

51. [1] $\frac{x}{m} = \frac{D}{N}$

$d\left(\frac{1}{C}\right) = \frac{dx}{K_m\varepsilon_0 A} = \frac{dx}{K\varepsilon_0 A\left(1+\frac{m}{N}\right)}$

$= \frac{dx}{K\varepsilon_0 A\left(1+\frac{x}{D}\right)}$

$\frac{1}{C_{eq}} = \int d\left(\frac{1}{C}\right) = \int_0^D \frac{Ddx}{K\varepsilon_0 A(D+x)}$

$\frac{1}{C_{eq}} = \frac{D}{K\varepsilon_0 A}\ln 2$

$C_{eq} = \frac{K\varepsilon_0 A}{D\ln 2}$

Therefore $\alpha = 1$.

@FAKE_CBSE_@RAJ_EDUNET

52. Capacities of conducting spheres are in the ratio of their radii. Let C_1 and C_2 be the capacities of S_1 and S_2, then

$$\frac{C_2}{C_1}=\frac{R}{r}$$

(a) Charges are distributed in the ratio of their capacities. Let in the first contact, charge acquired by S_2 is q_1.

Therefore, charge on S_1 will be $Q-q_1$.

$$\therefore \frac{q_1}{Q-q_1}=\frac{C_2}{C_1}=\frac{R}{r}$$

$$\therefore q_1=Q\left(\frac{R}{R+r}\right) \quad \ldots(i)$$

In the second contact, S_1 again acquires the same charge Q. Therefore, total charge in S_1 and S_2 will be

$$Q+q_1=Q\left(1+\frac{R}{R+r}\right)$$

This charge is again distributed in the same ratio. Therefore, charge on S_2 in second contact,

$$q_2=Q\left(1+\frac{R}{R+r}\right)\left(\frac{R}{R+r}\right)$$

$$=Q\left[\frac{R}{R+r}+\left(\frac{R}{R+r}\right)^2\right]$$

Similarly,

$$q_3=Q\left[\frac{R}{R+r}+\left(\frac{R}{R+r}\right)^2+\left(\frac{R}{R+r}\right)^3\right]$$

and $q_n=Q\left[\frac{R}{R+r}+\left(\frac{R}{R+r}\right)^2+\ldots+\left(\frac{R}{R+r}\right)^n\right]$

$$q_n=Q\frac{R}{r}\left[1-\left(\frac{R}{R+r}\right)^n\right] \quad \ldots(ii)$$

Therefore, electrostatic energy of S_2 after n such contacts

$$=\frac{q_n^2}{2(4\pi\varepsilon_0 R)} \text{ or } U_n=\frac{q_n^2}{8\pi\varepsilon_0 R}$$

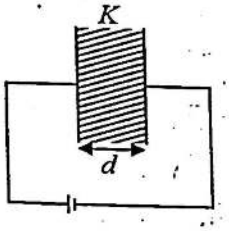
where, q_n can be written from Eq. (ii).

(b) As $n\to\infty$ $q_\infty=Q\frac{R}{r}$

$$\therefore U_\infty=\frac{q_\infty^2}{2C}=\frac{Q^2R^2/r^2}{8\pi\varepsilon_0 R}$$

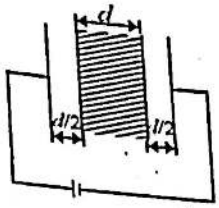
or $$U_\infty=\frac{Q^2R}{8\pi\varepsilon_0 r^2}$$

53. (b) For figure (a)



$$E_0=\frac{V}{d};\ C=\frac{K\varepsilon_0 A}{d}$$

Figure (b)

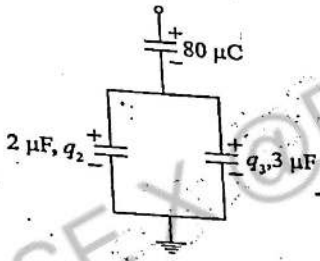


$$C'=\frac{\varepsilon_0 A}{2d-d+d/K};$$

$$C'=\frac{K\varepsilon_0 A}{(K+1)d};\ C'=\frac{C}{K+1}$$

54. (c) Between 3 μF and 2 μF (in parallel), total charge of 80 μC will distribute in direct ratio of capacity.

$$\frac{q_3}{q_2}=\frac{3}{2}$$



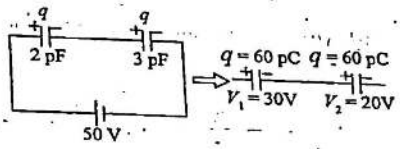
$$q_3=\left(\frac{3}{3+2}\right)(80)=48\mu C$$

55. (d) Charges on the capacitors are

$q_1=(30)(2)=60$ pC

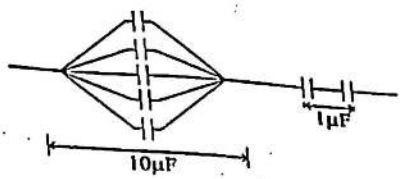
and $q_2=(20)(3)=60$ pC or $q_1=q_2=q$ (say).

The situation is similar as the two capacitors in series are first charged with a battery of emf 50 V and then disconnected.



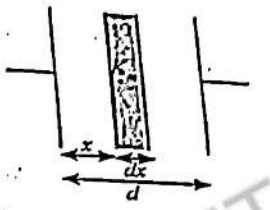
$\therefore$ When S_3 is closed, $V_1=30$V and $V_2=20$V.

56. (a) In series, $C=\frac{C_1C_2}{C_1+C_2}$



$$\therefore C_{net}=\frac{(10)(1)}{10+1}=\frac{10}{11}\mu F$$

57. [0.99 to 1.01]



$$\delta=dx=\frac{d}{N}\ \&\ \frac{m}{N}=\frac{x}{d}$$

$$K_m=K\left(1+\frac{m}{N}\right)\Rightarrow K_m=K\left(1+\frac{x}{d}\right)$$

$$C'=\frac{KmA\epsilon_0}{dx}$$

$$\frac{1}{C_{eq}}\int_0^d\frac{dx}{K_mA\epsilon_0}=\frac{1}{KA\epsilon_0}\int_0^d\frac{dx}{\left(1+\frac{x}{d}\right)}$$

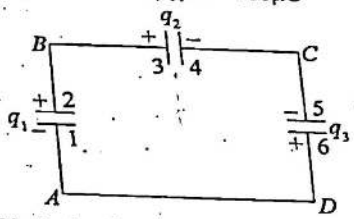
$$\Rightarrow\frac{1}{C_{eq}}\frac{dx}{K_mA\epsilon_0}=\left[\ell n\left(1+\frac{x}{d}\right)\right]_0^d$$

$$\Rightarrow\frac{1}{C_{eq}}\frac{dx}{K_mA\epsilon_0}=[\ell n2-\ell n(1)]$$

$$\Rightarrow C_{eq}=\frac{K_mA\epsilon_0}{d\ell n2}\Rightarrow\alpha=1$$

58. (a) Charge on capacitor A, before joining with an uncharged capacitor

$$q_A=CV=100(3)\mu C=300\mu C$$



Similarly, charge on capacitor B

$q_B=(180)(2)\mu C=360\mu C$

Let q_1, q_2 and q_3 be the charges on the three capacitors after joining them as shown in figure.

(q_1, q_2, and q_3 are in micro coulombs)

From conservation of charge

@FAKE CBSE X @RAJ EDUNET

Net charge on plates 2 and 3 before joining = net charge after joining

$\therefore\ 300 = q_1 + q_2$ ...(*i*)

Similarly, net charge on plates 4 and 5 before joining = net charge after joining

$-360 = -q_2 - q_3$

or $360 = q_2 + q_3$ ...(*ii*)

Applying Kirchhoff's second law in closed loop *ABCDA*

$$\frac{q_1}{3} - \frac{q_2}{2} + \frac{q_3}{2} = 0$$

or $2q_1 - 3q_2 + 3q_3 = 0$ ...(*iii*)

Solving Eqs. (*i*), (*ii*) and (*iii*), we get

$q_1 = 90\mu C$, $q_2 = 210\mu C$ and $q_3 = 150\ \mu C$

(*b*) (*i*) Electrostatic energy stored before, completing the circuit

$$U_i = \frac{1}{2}(3\times10^{-6})(100)^2 + \frac{1}{2}(2\times10^{-6})(180)^2 \quad \left(\because U = \frac{1}{2}CV^2\right)$$

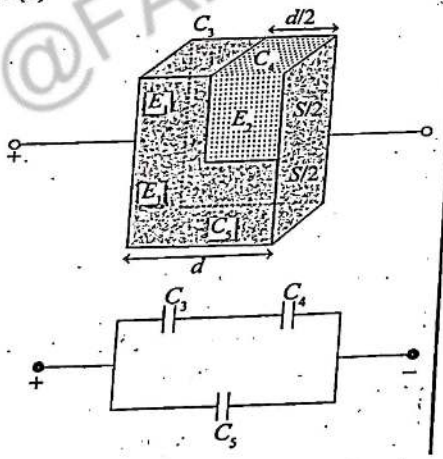
$= 4.74 \times 10^{-2}$ J or $U_i = 47.4$ mJ

(*ii*) Electrostatic energy stored after, completing the circuit

$$U_f = \frac{1}{2}\frac{(90\times10^{-6})^2}{(3\times10^{-6})} + \frac{1}{2}\frac{(210\times10^{-6})^2}{(2\times10^{-6})} + \frac{1}{2}\frac{(150\times10^{-6})^2}{(2\times10^{-6})} \quad \left[U = \frac{1}{2}\frac{q^2}{C}\right]$$

$= 1.8 \times 10^{-2}$ J or $U_f = 18$ mJ

59. (*d*)



$$C_1 = \frac{\varepsilon_0 s}{d}, C_3 = \frac{2\varepsilon_0\frac{s}{2}}{\frac{d}{2}} = \frac{2\varepsilon_0 s}{d}$$

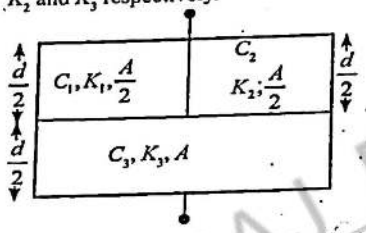
$$\Rightarrow\ C_4 = \frac{4\varepsilon_0\frac{s}{2}}{\frac{d}{2}} = \frac{4\varepsilon_0 s}{d}$$

and $C_5 = \frac{2\varepsilon_0\frac{s}{2}}{d} = \frac{\varepsilon_0 s}{d}$

$$C_2 = \frac{C_3C_4}{C_3 + C_4} + C_5 = \frac{4}{3}\frac{\varepsilon_0 s}{d} + \frac{\varepsilon_0 s}{d}$$

$$= \frac{7}{3}\frac{\varepsilon_0 s}{d} = \frac{7}{3}C_1 \Rightarrow \frac{C_2}{C_1} = \frac{7}{3}$$

60. (*c*) Let C_1, C_2 and C_3 are the Capacitance of capacitor with dielectric constant, K_1, K_2 and K_3 respectively.



$$\therefore\ C_1 = K_1\left(\frac{A}{2}\right)\frac{\varepsilon_0\times2}{d} = \frac{A\varepsilon_0K_1}{d}$$

$$\therefore\ C_2 = K_2\left(\frac{A}{2}\right)\frac{\varepsilon_0\times2}{d} = \frac{A\varepsilon_0K_2}{d}$$

$$\therefore\ C_3 = K_3(A)\frac{\varepsilon_0\times2}{d} = \frac{2A\varepsilon_0K_3}{d}$$

Again this C_{eq} and C_3 are in series

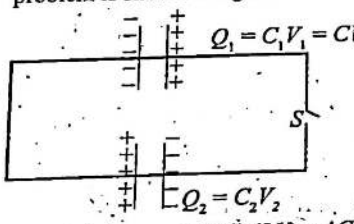
$$\therefore\ \frac{1}{C} = \frac{d}{A\varepsilon_0(K_1+K_2)} = \frac{d}{2A\varepsilon_0K_3}$$

But $C = \frac{KA\varepsilon_0}{d}$ for single equivalent capacitor

$$\therefore\ \frac{d}{KA\varepsilon_0} = \frac{d}{A\varepsilon_0(K_1+K_2)} + \frac{d}{2A\varepsilon_0K_3}$$

or $\frac{1}{K} = \frac{1}{K_1+K_2} + \frac{1}{2K_3}$.

61. (*b*) The diagramatic representation of given problem is shown in figure.



The net charge shared between the two capacitors is

$Q' = Q_2 - Q_1 = 4CV - CV = 3CV$

After closing the switch the two capacitors will have the same potential, say V'.

The net capacitance of the parallel combination of the two capacitors will be

$C' = C_1 + C_2 = C + 2C = 3C$

The potential difference across the capacitors will be

$$V' = \frac{Q'}{C'} = \frac{3CV}{3C} = V$$

The electrostatic energy of the capacitors will be

$$U' = \frac{1}{2}C'V' = \frac{1}{2}(3C)V^2 = \frac{3}{2}CV^2$$

62. (*a, c, d*) Battery is removed. Therefore, charge stored in the plates will remain constant.

$$Q = CV = \frac{\varepsilon_0 A}{d}V \text{ or } Q = \text{constant}.$$

Now, dielectric slab is inserted. Therefore, C will increase. New capacity will be,

$$C' = KC = \frac{\varepsilon_0 KA}{d} \Rightarrow V' = \frac{Q}{C'} = \frac{V}{K}$$

and new electric field, $E = \frac{V'}{d} = \frac{V}{K\cdot d}$

Potential energy stored in the capacitor,

Initially, $U_i = \frac{1}{2}CV^2 = \frac{\varepsilon_0 AV^2}{2d}$

Finally,

$$U_f = \frac{1}{2}C'V'^2 = \frac{1}{2}\left(\frac{K\varepsilon_0 A}{d}\right)\left(\frac{V}{K}\right)^2 = \frac{\varepsilon_0 AV^2}{2Kd}$$

Work done on the system will be

$$|\Delta U| = \frac{\varepsilon_0 AV^2}{2d}\left(1 - \frac{1}{K}\right)$$

$\therefore$ Correct options are (*a*), (*c*) and (*d*).

63. (*b, d*) Charging battery is removed. Therefore, q = constant

Distance between the plates is increased. Therefore, C decreases.

Now, $V = q/C$, q is constant and C is decreasing.

Therefore, V should increase.

$U = \frac{1}{2}\frac{q^2}{C}$ again q is constant and C is decreasing.

Therefore U should increase.

$\therefore$ Correct options are (*b*) and (*d*).

@FAKE_CBSE_X_RAJ_EDUNET

64. (a, d) $C_1 = \frac{K\varepsilon_0 A/3}{d}$

Let $C_2 = \frac{\varepsilon_0 2A/3}{d}$ (for region without dielectric)

Then $C = C_1 + C_2 = \frac{K\varepsilon_0 A/3}{d} + \frac{\varepsilon_0 2A/3}{d}$

$C = \frac{\varepsilon_0 A}{3d}(K+2)$

$\frac{C}{C_1} = \frac{K+2}{K}$

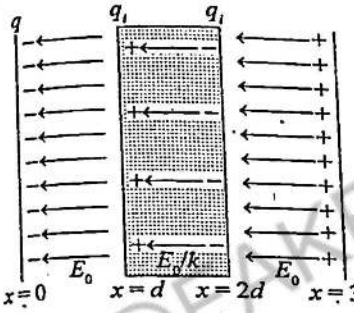
Since potential difference is same and gap is same

$E_1 = E_2$

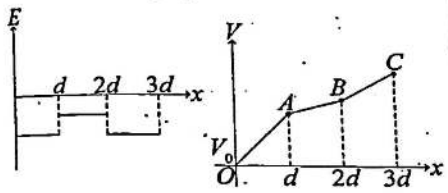
$\frac{E_1}{E_2} = 1$

$\frac{Q_1}{Q_2} = \frac{C_1}{C_2} = \frac{K}{2}$

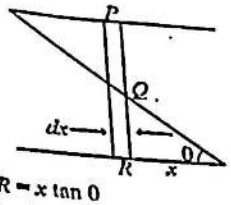
65. (b, c) The magnitude and direction of electric field at different points are shown in figure, The direction of the electric field remains the same. Hence, option (b) is correct. Similarly, electric lines always flow from higher potential to lower potential, therefore, electric potential increases continuously as we move from $x = 0$ to $x = 3d$.



Option (c) hence is also correct. The variation of electric field (E) and potential (V) with x will be as shown below.



66. Let length and breadth of the capacitor be l and b respectively and d be the distance between the plates as shown in figure. Then, consider a strip at a distance x of width dx.



Now, $QR = x \tan\theta$

and $PQ = d - x\tan\theta$

where, $\tan\theta = d/l$

Using the formula of

$$C = \frac{\varepsilon_0 A}{d - t_1 - t_2 + (t_1/K_1) + (t_2/K_2)}$$

We have,

Small capacitance between P and R is

$$dC = \frac{\varepsilon_0 (b\,dx)}{d - PQ - PR + \frac{PQ}{K_1} + \frac{QR}{K_2}}$$

Substituting the values of PQ and QR with

$\tan\theta = \frac{d}{l}$

we have,

$$dC = \frac{\varepsilon_0 A K_1 K_2}{d\{K_2 l + (K_1 - K_2)x\}}dx \qquad [bl = A]$$

Now all such small capacitors from $x = 0$ and $x = l$ will be in parallel as potential difference between them will be same.

Hence, the net capacitance of the given parallel plate capacitor is obtained by adding such infinitesimal capacitors placed parallel from $x = 0$ to $x = l$

i.e.

$$C_R = \int_{x=0}^{x=l} dC = \int_0^l \frac{\varepsilon_0 A K_1 K_2}{d\{K_2 l + (K_1 - K_2)x\}}dx$$

Finally we get

$$C_R = \frac{K_1 K_2 \varepsilon_0 A}{(K_2 - K_1)d}\ln\frac{K_2}{K_1}$$

$$= \frac{CK_1K_2}{K_2 - K_1}\ln\frac{K_2}{K_1} \text{ where, } C = \frac{\varepsilon_0 A}{d}$$

67. (a) Capacitor A is a combination of two capacitors C_K and C_O in parallel. Hence,

$$C_A = C_K + C_O = \frac{K\varepsilon_0 A}{d} + \frac{\varepsilon_0 A}{d}$$

$$= (K+1)\frac{\varepsilon_0 A}{d}$$

Here, $A = 0.02\ m^2$. Substituting the values, we have

$$C_A = (9+1)\frac{8.85\times10^{-12}(0.02)}{(8.85\times10^{-4})}$$

$C_A = 2.0 \times 10^{-9}$ F

Energy stored in capacitor A, when connected with a 110 V battery is

$$U_A = \frac{1}{2}C_A V^2 = \frac{1}{2}(2\times10^{-9})(110)^2$$

$U_A = 1.21 \times 10^{-5}$ J

(b) Charge stored in the capacitor

$q_A = C_A V = (2.0 \times 10^{-9})(110)$

$\Rightarrow q_A = 2.2 \times 10^{-7}$ C

Now, this charge remains constant even after battery is disconnected. When the slab is removed, capacitance of A will get reduced. Let it be C'_A

$$C'_A = \frac{\varepsilon_0(2A)}{d} = \frac{(8.85\times10^{-12})(0.04)}{8.85\times10^{-4}}$$

$C'_A = 0.4 \times 10^{-9}$ F

Energy stored in this case would be

$$U'_A = \frac{1}{2}\frac{(q_A)^2}{C'_A} = \frac{1}{2}\frac{(2.2\times10^{-7})^2}{(0.4\times10^{-9})}$$

$U'_A = 6.05 \times 10^{-5}\ J > U_A$

Therefore, work done to remove the slab would be

$W = U'_A - U_A = (6.05 - 1.21) \times 10^{-5}$ J

or $W = 4.84 \times 10^{-5}$ J

(c) Capacity of B when filled with dielectric is

$$C_B = \frac{K\varepsilon_0 A}{d} = \frac{(9)(8.85\times10^{-12})(0.02)}{(8.85\times10^{-4})}$$

$C_B = 1.8 \times 10^{-9}$ F

These two capacitors are in parallel. Therefore, net capacitance of the system is

$C = C'_A + C_B = (0.4 + 1.8) \times 10^{-9}$ F

$C = 2.2 \times 10^{-9}$ F

Charge stored in the system is $q = q_A$

$= 2.2 \times 10^{-7}$ C

Therefore, energy stored, $U = \frac{1q^2}{2C}$

$$U = \frac{1}{2}\frac{(2.2\times10^{-7})^2}{(2.2\times10^{-9})}$$

or $U = 1.1 \times 10^{-5}$ J

68. (d) $q_1 = C_1 V = 2V = q$ (say)

This charge will remain constant after switch is shifted from position 1 to position 2.

$$U_i = \frac{1}{2}\frac{q^2}{C_i} = \frac{q^2}{2\times2} = \frac{q^2}{4}$$

$$U_f = \frac{1}{2}\frac{q^2}{C_f} = \frac{q^2}{2\times10} = \frac{q^2}{20}$$

$\therefore$ Energy dissipated $= U_i - U_f = \frac{q^2}{5}$

© BHIKE_CBSE_SCIENCE_ORAJ_BLOGSPOT.NET

This energy dissipated $\left(=\frac{q^2}{5}\right)$ is 80% of the initial stored energy $\left(=\frac{q^2}{4}\right)$.

69. *(b, d)* When S_1 is closed charge on C_1 will be $Q_0 = C.2V_0 = 2CV_0$

After switch S_1 is released and S_2 is pressed

Since $C_1 = C_2 = C$.

$$Q_1 = Q_2 = \frac{Q_0}{2} = CV_0$$

Now when S_2 is released and S_3 is pressed potential difference across C_2 is $-V_0$ so

$Q_2 = -CV_0$

70. *[8]* Potential difference across the terminals of C_3 is $2V$

$\therefore\ Q_3 = CV = (4\mu)(2) = 8\mu C$

71. [1.5]

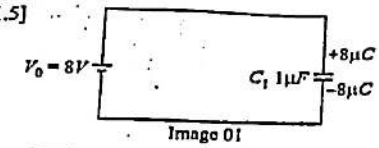


Image 01

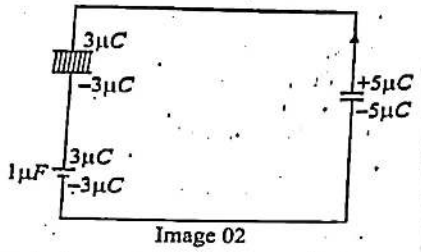


Image 02

From image 1, when switch S_1 is opened and switch S_2 is closed, then capacitor C_3 is charged to $5\mu C$, thus, the net charge $8\mu C$ $-5\mu C = 3\mu C$ resides on C_1 and C_2, as they are connected in series.

Now, looking at Image 2, apply Kirchoff's loop law,

$$\frac{q_1}{C_1} + \frac{q_2}{C_2} = \frac{q_3}{C_3}$$

$$\frac{q_1}{C_1} + \frac{q_2}{C_1 \epsilon_r} = \frac{q_3}{C_3}$$

$$\frac{q}{C}\left(1 + \frac{1}{\epsilon_r}\right) = \frac{5}{1} = 5$$

$$3\left(1 + \frac{1}{\epsilon_r}\right) = 5$$

Thus, $\epsilon_r = 1.5$

@FAKE_CBSE X @RAJ_EDUNET

19 Current Electricity

JEE-Main

Current Density, Resistance, Coefficient of Resistance, Drift Velocity, Ohm's Law and Conductivity, Resistivity

1. The electric current through a wire varies with time as $I = I_0 + \beta t$. where $I_0 = 20$ A and $\beta = 3$ A/s. The amount of electric charge crossed through a section of the wire in 20 s is:
[29 Jan, 2024 (Shift-I)]
(a) 80 C (b) 1000 C (c) 800 C (d) 1600 C

2. An electric toaster has resistance of 60 Ω at room temperature (27°C). The toaster is connected to a 220 V supply. If the current flowing through it reaches 2.75 A, the temperature attained by toaster is around : (if $\alpha = 2 \times 10^{-4}$/°C)
[30 Jan, 2024 (Shift-I)]
(a) 694°C (b) 1235°C (c) 1694°C (d) 1667°C

3. Two conductors have the same resistances at 0°C but their temperature coefficients of resistance are α_1 and β_2. The respective temperature coefficients for their series and parallel combinations are:
[31 Jan, 2024 (Shift-I)]
(a) $\alpha_1 + \alpha_2, \frac{\alpha_1 + \alpha_2}{2}$ (b) $\frac{\alpha_1 + \alpha_2}{2}, \frac{\alpha_1 + \alpha_2}{2}$
(c) $\alpha_1 + \alpha_2, \frac{\alpha_1 \alpha_2}{\alpha_1 + \alpha_2}$ (d) $\frac{\alpha_1 + \alpha_2}{2}, \alpha_1 + \alpha_2$

4. The current in a conductor is expressed as $I = 3t^2 + 4t^3$, where I is in Ampere and t is in second. The amount of electric charge that flows through a section of the conductor during $t = 1$s to $t = 2$s is _____ C.
[1 Feb, 2024 (Shift-I)]

5. The resistances of the platinum wire of a platinum resistance thermometer at the ice point and steam point are 8 Ω and 10 Ω respectively. After inserting in a hot bath of temperature 400°C, the resistance of platinum wire is :
[04 April, 2024 (Shift-I)]
(a) 2Ω (b) 16Ω (c) 8Ω (d) 10Ω

6. Two wires A and B are made up of the same material and have the same mass. Wire A has radius of 2.0 mm and wire B has radius of 4.0 mm. The resistance of wire B is 2Ω. The resistance of wire A is _____Ω.
[04 April, 2024 (Shift-II)]

7. A wire of resistance R and radius r is stretched till its radius became $r/2$. If new resistance of the stretched wire is xR, then value of x is _____.
[06 April, 2024 (Shift-I)]

8. Resistance of a wire at 0°C, 100°C and t°C is found to be 10 Ω, 10.2 Ω and 10.95 Ω respectively.
The temperature t in Kelvin scale is _____.
[08 April, 2024 (Shift-I)]

9. At room temperature (27°C), the resistance of a heating element is 50 Ω. The temperature coefficient of the material is 2.4×10^{-4}°C^{-1}. The temperature of the element, when its resistance is 62 Ω, is ..... °C.
[09 April, 2024 (Shift-II)]

10. The length of a given cylindrical wire is increased to double of its original length. The percentage increase in the resistance of the wire will be _____. %.
[25 June, 2022 (Shift-II)]

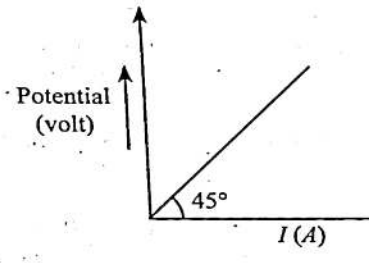
11. An aluminium wire is stretched to make its length, 0.4% larger. The percentage change in resistance is:
[26 June, 2022 (Shift-I)]
(a) 0.4% (b) 0.2% (c) 0.8% (d) 0.6%

12. The current density in a cylindrical wire of radius 4 mm is 4×10^6 Am^{-2}. The current through the outer portion of the wire between radial distance $\frac{R}{2}$ and R is _____ πA.
[27 June, 2022 (Shift-I)]

13. The current density in a cylindrical wire of radius $r = 4.0$ mm is 1.0×10^6 A/m^2. The current through the outer portion of the wire between radial distances $\frac{r}{2}$ and r is $x\pi$ A; where x is _____
[27 June, 2022 (Shift-II)]

14. Resistance of the wire is measured as 2 Ω and 3 Ω at 10°C and 30°C respectively. Temperature co-efficient of resistance of the material of the wire is:
[28 June, 2022 (Shift-II)]
(a) 0.033°C^{-1} (b) −0.033°C^{-1}
(c) 0.011°C^{-1} (d) 0.055°C^{-1}

15. The variation of applied potential and current flowing through a given wire is shown in figure. The length of wire is 31.4 cm. The diameter of wire is measured as 2.4 cm. The resistivity of the given wire is measured as $x \times 10^{-3}$ Ωcm. The value of x is _____.
[Take $\pi = 3.14$]



[29 June, 2022 (Shift-

@FAKE_CBSE_Y@AJ_DUNET

16. A wire of resistance R_1 is drawn out so that its length is increased by twice of its original length. The ratio of new resistance to original resistance is **[28 July, 2022 (Shift-I)]**

(a) 9 : 1 (b) 1 : 9
(c) 4 : 1 (d) 3 : 1

17. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R.

Assertion (A): Alloys such as constantan and manganin are used in making standard resistance coils.

Reason (R): Constantan and manganin have very small value of temperature coefficient of resistance.

In the light of the above statements, choose the correct answer from the options given below. **[29 July, 2022 (Shift-II)]**

(a) Both (A) and (R) are true and (R) is the correct explanation of A
(b) Both (A) and (R) are true but (R) is NOT the correct explanation of A
(c) (A) is true but (R) is false
(d) (A) is false but (R) is true

(a) $0.033°C^{-1}$ (b) $-0.033°C^{-1}$
(c) $0.011°C^{-1}$ (d) $0.055°C^{-1}$

18. *A* 1 m long wire is broken into two unequal parts *X* and *Y*. The *X* part of the wire is stretched into another wire *W*. Length of *W* is twice the length of *X* and the resistance of *W* is twice that of *Y*. Find the ratio of length of *X* and *Y*. **[29 July, 2022 (Shift-II)]**

(a) 1 : 4 (b) 1 : 2
(c) 4 : 1 (d) 2 : 1.

19. A current through a wire depends on time as $i = \alpha_0 t + \beta t^2$ Where $\alpha_0 = 20$ A/s and $\beta = 8 As^{-2}$. Find the charge crossed through a section of the wire in 15 s. **[24 Feb, 2021 (Shift-I)]**

(a) 2100 C (b) 2250 C (c) 260 C (d) 11250 C

20. A cylindrical wire of radius 0.5 mm and conductivity 5×10^7 S/m is subjected to an electric field of 10 mV/m. The expected value of current in the wire will be $x^3\pi$mA. The value of x is _____. **[24 Feb, 2021 (Shift-II)]**

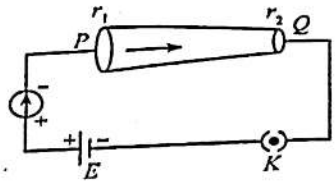
21. A current of 10 *A* exists in a wire of cross-sectional area of $5mm^2$ with a drift velocity of 2×10^{-3} ms^{-1}. The number of free electrons in each cubic meter of the wire **[17 March, 2021 (Shift-I)]**

(a) 2×10^{25} (b) 1×10^{23}
(c) 2×10^{6} (d) 625×10^{25}

22. A current of 5A is passing through a non-linear magnesium wire of cross-section 0.04 m^2. At every point the direction of current density is at an angle of 60° with the unit vector of area of cross-section. The magnitude of electric field at every point of the conductor is (Resistivity of magnesium, $\rho = 44 \times 10^{-8} \Omega m$) **[20 July, 2021 (Shift-I)]**

(a) 11×10^{-7} V/m (b) 11×10^{-2} V/m
(c) 11×10^{-5} V/m (d) 11×10^{-3} V/m

23. In the given figure, a battery of emf *E* is connected across a conductor *PQ* of length '*l*' and different area of cross- sections by having radii r_1 and r_2 ($r_2 < r_1$).



Choose the correct option as one moves from *P* to *Q*: **[27 July, 2021 (Shift-I)]**

(a) All of these.
(b) Electron current decreases.
(c) Drift velocity of electron increases.
(d) Electric field decreases.

24. The resistance of a conductor at 15°C is 16Ω and at 100°C is 20Ω. What will be the temperature coefficient of resistance of the conductor ? **[27 July, 2021 (Shift-II)]**

(a) $0.003°C^{-1}$ (b) $0.042°C^{-1}$ (c) $0.033°C^{-1}$ (d) $0.010°C^{-1}$

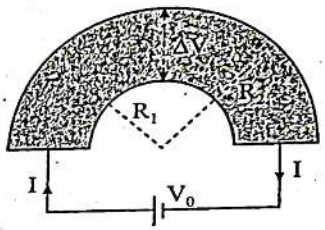
25. Consider four conducting materials copper, tungsten, mercury and aluminium with resistivity ρ_C, ρ_T, ρ_M and ρ_A respectively. Then **[2 Sep, 2020 (Shift-I)]**

(a) $\rho_A > \rho_T > \rho_C$ (b) $\rho_M > \rho_A > \rho_C$
(c) $\rho_C > \rho_A > \rho_T$ (d) $\rho_A > \rho_M > \rho_C$

26. A circuit to verify Ohm's law uses ammeter and voltmeter in series or parallel connected correctly to the resistor. In the circuit: **[2 Sep, 2020 (Shift-I)]**

(a) ammeter is always used in parallel and voltmeter is series.
(b) both ammeter and voltmeter must be connected in parallel.
(c) ammeter is always connected in series and voltmeter in parallel.
(d) both, ammeter and voltmeter must be connected in series.

27. Shown in the figure is a semicircular metallic strip that has thickness t and resistivity ρ. Its inner radius is R_1 and outer radius is R_2. If a voltage V_0 is applied between its two ends, a current I flows in it. In addition, it is observed that a transverse voltage ΔV develops between its inner and outer surfaces due to purely kinetic effects of moving electrons (ignore any role of the magnetic field due to the current). Then (figure is schematic and not drawn to scale) **[JEE Adv, 2020]**



(a) $I = \frac{V_0 t}{\pi \rho} \ln\left(\frac{R_2}{R_1}\right)$
(b) the outer surface is at a higher voltage than the inner surface
(c) the outer surface is at a lower voltage than the inner surface
(d) $\Delta V \propto I^2$

28. Drift speed of electrons, when 1.5 A of current flows in a copper wire of cross section 5 mm^2, is v. If the electron density in copper is $9 \times 10^{28}/m^3$ the value of v in mm/s is close to (Take charge of electron to be $= 1.6 \times 10^{-19}$ C) **[9 Jan, 2019 (Shift-I)]**

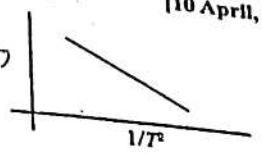
(a) 0.02 (b) 3
(c) 2 (d) 0.2

29. In a conductor, if the number of conduction electrons per unit volume is 8.5×10^{28} m^{-3} and mean free time is 25fs (femto second), its approximate resistivity is: ($m_e = 9.1 \times 10^{-31}$ kg) **[9 Apr, 2019 (Shift-II)]**

(a) 10^{-5} Ωm (b) 10^{-6} Ωm (c) 10^{-7} Ωm (d) 10^{-8} Ωm

@FAST CODE X @RAJ_PUNIT

30. In an experiment, the resistance of a material is plotted as a function of temperature (in some range). As shown in the figure, it is a straight line. One may conclude that: **[10 April, 2019 (Shift-I)]**



(a) $R(T) = R_0 e^{T^2/T_0^2}$ (b) $R(T) = \frac{R_0}{T^2}$

(c) $R(T) = R_0 e^{-T^2/T_0^2}$ (d) $R(T) = R_0 e^{-(T_0^2/T^2)}$

31. A current of 5 A passes through a copper conductor (resistivity = 1.7×10^{-8} Ωm) of radius of cross-section 5 mm. Find the mobility of the charges if their drift velocity is 1.1×10^{-3} m/s. **[10 April, 2019 (Shift-I)]**

(a) 1.8 m²/Vs (b) 1.0 m²/Vs

(c) 1.3 m²/Vs (d) 1.5 m²/Vs

32. Space between two concentric conducting spheres of radii a and $b(b > a)$ is filled with a medium of resistivity ρ. The resistance between the two spheres will be **[10 April, 2019 (Shift-II)]**

(a) $\frac{\rho}{2\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$ (b) $\frac{\rho}{2\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$

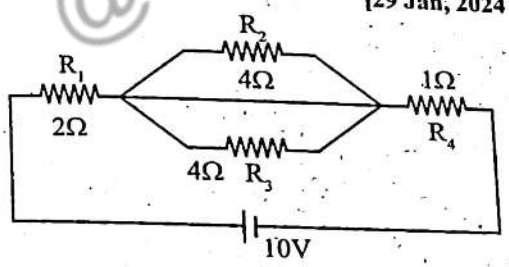
(c) $\frac{\rho}{4\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$ (d) $\frac{\rho}{4\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$

Series and Parallel Combination of Resistance

33. A wire of resistance R and length L is cut into 5 equal parts. If these parts are joined parallely, then resultant resistance will be: **[27 Jan, 2024 (Shift-I)]**

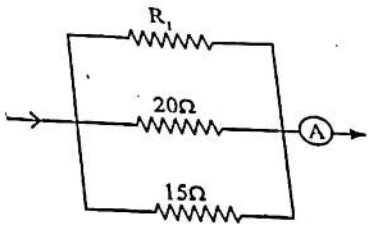
(a) $\frac{1}{25}R$ (b) $\frac{1}{5}$ R (c) 25 R (d) 5 R

34. In the given circuit, the current in resistance R_3 is: **[29 Jan, 2024 (Shift-II)]**

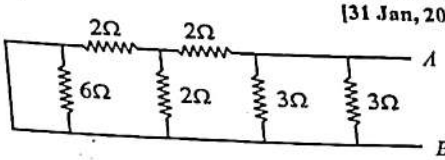


(a) 1 A (b) 1.5 A (c) 2 A (d) 2.5 A

35. In the given circuit, the current flowing through the resistance 20Ω is 0.3 A, while the ammeter reads 0.9 A. The value of R_1 is _____ Ω. **[29 Jan, 2024 (Shift-II)]**

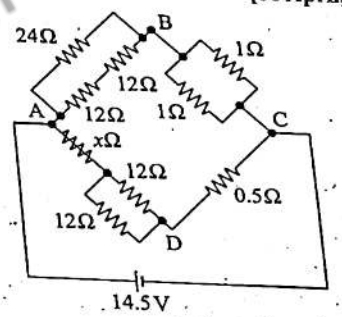


36. Equivalent resistance of the following network is _____ Ω. **[31 Jan, 2024 (Shift-I)]**



37. A wire of resistance 20 Ω is divided into 10 equal parts. A combination of two parts are connected in parallel and so on. Now resulting pairs of parallel combination are connected in series. The equivalent resistance of final combination is _____Ω. **[05 April, 2024 (Shift-II)]**

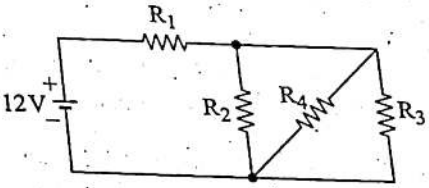
38. The value of unknown resistance (x) for which the potential difference between B and D will be zero in the arrangement shown, is: **[06 April, 2024 (Shift-I)]**



(a) 3 Ω (b) 9 Ω

(c) 6 Ω (d) 42 Ω

39. In the given figure $R_1 = 10\Omega, R_2 = 8\Omega, R_3 = 4\Omega$ and $R_4 = 8\Omega$. Battery is ideal with emf 12V. Equivalent resistant of the circuit and current supplied by battery are respectively. **[05 April, 2024 (Shift-I)]**

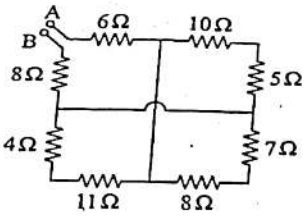


(a) 12 Ω and 11.4 A (b) 10.5 Ω and 1.14 A

(c) 10.5 Ω and 1 A (d) 12 Ω and 1 A

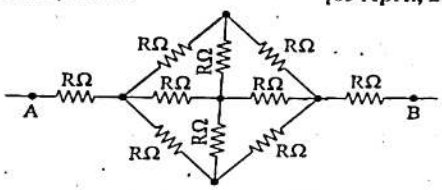
40. The equivalent resistance between A and B is: **[09 April, 2024 (Shift-I)]**

@FAKE_CBSE X @RAI_EDUNET



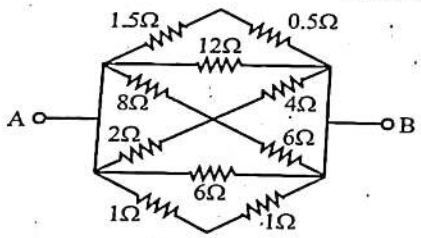
(a) 18 Ω (b) 25 Ω
(c) 27 Ω (d) 19 Ω

41. The effective resistance between A and B, if resistance of each resistor is R, will be **[09 April, 2024 (Shift-II)]**



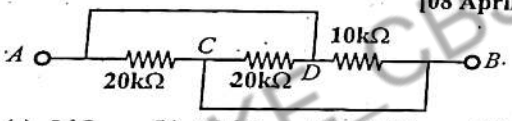
(a) $\frac{2}{3}R$ (b) $\frac{8R}{3}$ (c) $\frac{5R}{3}$ (d) $\frac{4R}{3}$

42. The equivalent resistance between A and B is _____ **[30 Jan, 2023 (Shift-II)]**



(a) $\frac{2}{3}\Omega$ (b) $\frac{1}{2}\Omega$ (c) $\frac{3}{2}\Omega$ (d) $\frac{1}{3}\Omega$

43. The equivalent resistance between A and B as shown in figure is: **[08 April, 2023 (Shift-II)]**



(a) 5 kΩ (b) 30 kΩ (c) 10 kΩ (d) 20 kΩ

44. Equivalent resistance between the adjacent corners of a regular n-sided polygon of uniform wire of resistance R would be: **[1 Feb, 2023 (Shift-II)]**

(a) $\frac{(n-1)R}{n^2}$ (b) $\frac{(n-1)R}{(2n-1)}$ (c) $\frac{n^2R}{n-1}$ (d) $\frac{(n-1)R}{n}$

45. Given below are two statements:

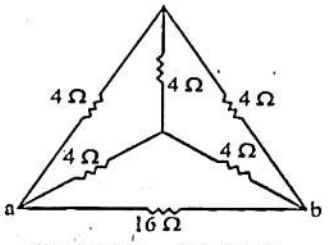
Statement-I: The equivalent resistance of resistors in a series combination is smaller than least resistance used in the combination.

Statement-II: The resistivity of the material is independent of temperature.

In the light of the above statements, choose the correct answer from the options given below: **[15 April, 2023 (Shift-I)]**

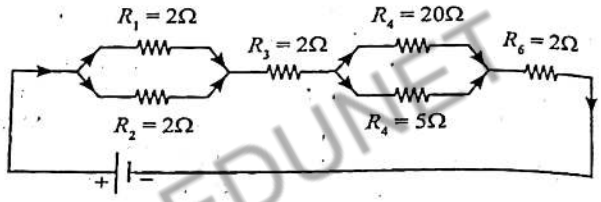
(a) Statement-I is false but Statement-II is true
(b) Both Statement-I and Statement-II are false
(c) Statement-I is true but Statement-II is false
(d) Both Statement-I and Statement-II are true

46. The equivalent resistance of the circuit shown below between points a and b is: **[10 April, 2023 (Shift-I)]**



(a) 24 Ω (b) 3.2 Ω (c) 20 Ω (d) 16 Ω

47. As shown in the figure, a network of resistors is connected to a battery of 24 V with an internal resistance of 3Ω. The currents through the resistors R_4 and R_5 are I_4 and I_5 respectively. The values of I_4 and I_5 are: **[24 Jan, 2023 (Shift-I)]**



(24V, 3Ω)

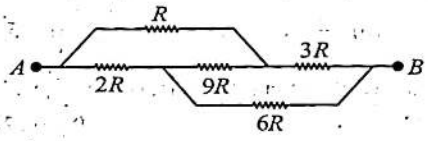
(a) $I_4 = \frac{8}{5}A$ and $I_5 = \frac{2}{5}A$

(b) $I_4 = \frac{24}{5}A$ and $I_5 = \frac{6}{5}A$

(c) $I_4 = \frac{6}{5}A$ and $I_5 = \frac{24}{5}A$

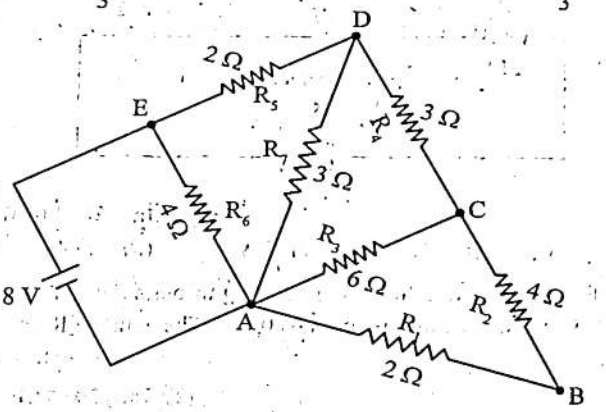
(d) $I_4 = \frac{2}{5}A$ and $I_5 = \frac{8}{5}A$

48. The equivalent resistance between A and B of the network shown in figure: **[01 Feb, 2023 (Shift-I)]**



(a) $11\frac{2R}{3}$ (b) 14 R (c) 21 R (d) $\frac{8}{3}R$

49.



@RAKESH CBSE X @RAJ EDUNET

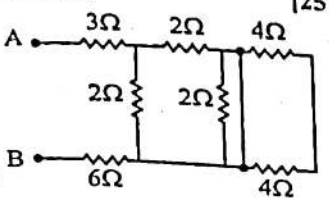
The current flowing through R_2 is:

[11 April, 2023 (Shift-II)]

(a) $\frac{2}{3}A$ (b) $\frac{1}{4}A$ (c) $\frac{1}{2}A$ (d) $\frac{1}{3}A$

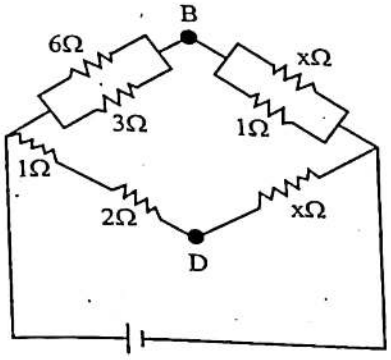
In the given circuit, the equivalent resistance between the terminal A and B is _____ Ω.

[25 Jan, 2023 (Shift-I)]



If the potential difference between B and D is zero, the value of x is $\frac{1}{n}\Omega$. The value of n is

[30 Jan, 2023 (Shift-II)]



10 resistors each of resistance 10Ω can be connected in such as to get maximum and minimum equivalent resistance. The ratio of maximum and minimum equivalent resistance will be _____.

[10 April, 2023 (Shift-I)]

Two metallic wires of identical dimensions are connected in series. If s_1 and s_2 are the conductivities of the these wires respectively, the effective conductivity of the combination is:

[29 July, 2022 (Shift-I)]

(a) $\frac{\sigma_1\sigma_2}{\sigma_1+\sigma_2}$ (b) $\frac{2\sigma_1\sigma_2}{\sigma_1+\sigma_2}$

(c) $\frac{\sigma_1+\sigma_2}{2\sigma_1\sigma_2}$ (d) $\frac{\sigma_1+\sigma_2}{\sigma_1\sigma_2}$

Eight copper wire of length l and diameter d are joined in parallel to from a single composite conductor of resistance R. If a single copper wire of length $2l$ have the same resistance (R) then its diameter will be _____d.

[25 July, 2022 (Shift-I)]

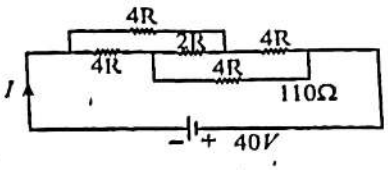
What will be the most suitable combination of three resistors $A = 2\Omega$, $B = 4\Omega$, $C = 6\Omega$ so that $\left(\frac{22}{3}\right)$ is equivalent resistance of combination?

[24 June, 2022 (Shift-II)]

(a) Parallel combination of A and C connected in series with B.
(b) Parallel combination of A and B connected in series with C.
(c) Series combination of A and C connected in parallel with B.
(d) Series combination of B and C connected in parallel with A.

The current I in the given circuit will be: [26 July, 2022 (Shift-I)]

(a) 10 A (b) 20 A (c) 4 A (d) 40 A



Given below are two statements:

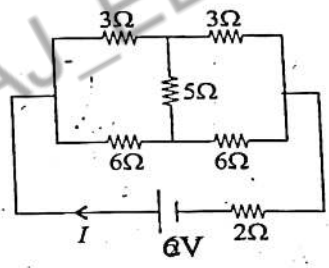
Statement-I: A uniform wire of resistance 80Ω is cut into four equal parts. These parts are now connected in parallel. The equivalent resistance of the combination will be 5Ω.

Statement-II: Two resistances $2R$ and $3R$ are connected in parallel in a electric circuit. The value of thermal energy developed in $3R$ and $2R$ will be in the ratio 3 : 2.

In the light of the above statements, choose the most appropriate answer from the option given below [28 July, 2022 (Shift-II)]

(a) Both statement-I and statement-II are correct
(b) Both statement-I and statement-II are incorrect
(c) Statement-I is correct but statement-II is incorrect
(d) Statement-I is incorrect but statement-II is correct

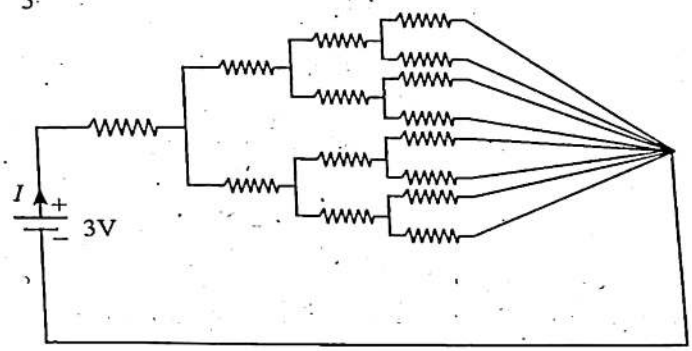
A battery of 6V is connected to the circuit as shown below. The current I drawn from the battery is: [26 July, 2022 (Shift-II)]



(a) 1A (b) 2A (c) $\frac{6}{11}A$ (b) $\frac{4}{3}A$

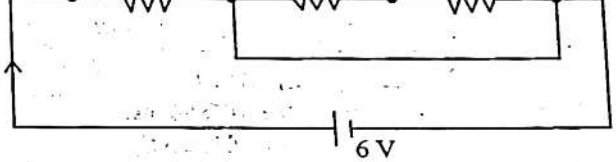
All resistances in figure are 1 Ω each. The value of current 'I' is $\frac{a}{5}A$. The value of a is _____.

[28 June, 2022 (Shift-II)]



The current I flowing through the given circuit will be _____ A.

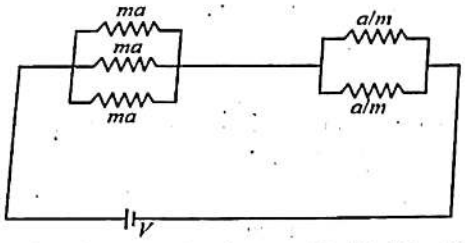
[29 July, 2022 (Shift-I)]



@FAKE_CBSE_X @RAJ_EDUNET

61. In the given circuit 'a' is an arbitrary constant. The value of m for which the equivalent circuit resistance is minimum, will be $\sqrt{\frac{x}{2}}$.

The value of x is _____ **[27 June, 2022 (Shift-II)]**

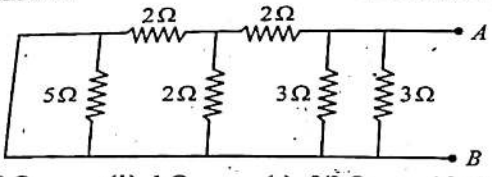


62. If you are provided a set of resistances 2Ω, 4Ω, 6Ω and 8Ω. Connect these resistances so as to obtain an equivalent resistance of $\frac{46}{3}\Omega$.

[26 Aug, 2021 (Shift-II)]

(a) 4 Ω and 6 Ω are in parallel with 2 Ω and 8 Ω in series.
(b) 6 Ω and 8 Ω are in parallel with 2 Ω and 4 Ω in series.
(c) 2 Ω and 4 Ω are in parallel with 6 Ω and 8 Ω in series.
(d) 2 Ω and 6 Ω are in parallel with 4 Ω and 8 Ω in series.

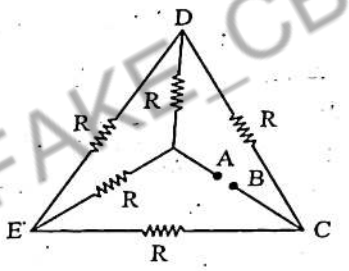
63. The equivalent resistance of the given circuit between the terminals A and B is: **[31 Aug, 2021 (Shift-II)]**



(a) 0 Ω (b) 1 Ω (c) 9/2 Ω (d) 3 Ω

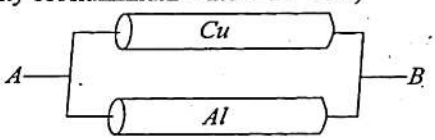
64. Five equal resistances are connected in a network as shown in figure. The net resistance between the points A and B is: **[26 Feb, 2021 (Shift-I)]**

(a) $\frac{3R}{2}$ (b) R (c) $\frac{R}{2}$ (d) 2R



65. A Copper (Cu) rod of length 25cm and cross – sectional area 3 mm² is joined with a similar aluminium (Al) rod as shown in figure. Find the resistance of the combination between the ends A and B. **[22 July, 2021 (Shift-II)]**

(Take Resistivity of Copper = 1.7×10^{-8} Ωm,
Resistivity of Aluminium = 2.6×10^{-8} Ωm)



(a) 0.858 mΩ (b) 0.0858 mΩ
(c) 1.420 mΩ (d) 2.170 mΩ

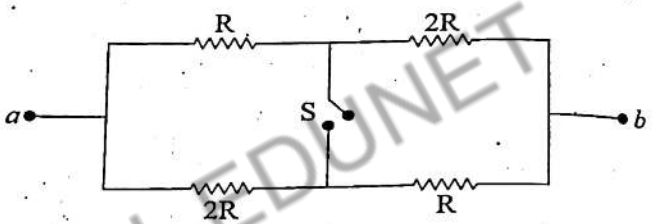
66. What equal length of an iron wire and a copper-nickel alloy wire, each of 2 mm diameter connected parallel to give an equivalent resistance of 3Ω? **[26 Aug, 2021 (Shift-I)]**
(Given resistivities of iron and copper-nickel alloy wire are 12μΩ cm and 51μΩ cm respectively)

(a) 110 m (b) 90 m
(c) 82 m (d) 97 m

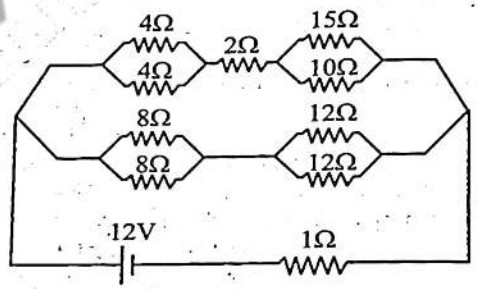
67. Two resistors $R_1 = (4 \pm 0.8)\Omega$ and $R_2 = (4 \pm 0.4)\Omega$ are connected in parallel. The equivalent resistance of their parallel combination will be: **[1 Sep, 2021 (Shift-II)]**

(a) $(4 \pm 0.4)\Omega$ (b) $(2 \pm 0.3)\Omega$
(c) $(4 \pm 0.3)\Omega$ (d) $(2 \pm 0.4)\Omega$

68. The ratio of the equivalent resistance of the network (shown in figure) between the points a and b when switch is open and switch is closed is $x : 8$. The value of x is _____. **[27 Aug, 2021 (Shift-II)]**

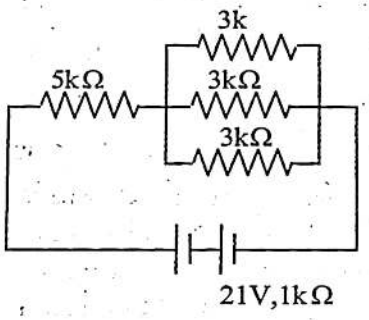


69. The voltage drop across 15 Ω resistance in the given figure will be _____ V. **[31 Aug, 2021 (Shift-I)]**



70. A square shaped wire with resistance of each side 3 Ω is bent to form a complete circle. The resistance between two diametrically opposite points of the circle in unit of Ω will be _____. **[31 Aug, 2021 (Shift-I)]**

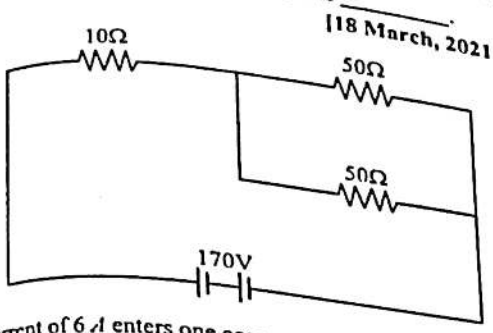
71. In the figure given, the electric current flowing through the 5 kΩ resistor is 'x' mA. The value of x to the nearest integer is _____. **[16 March, 2021 (Shift-I)]**



@FAKE_CBSE_K@RAJ_EDUNET

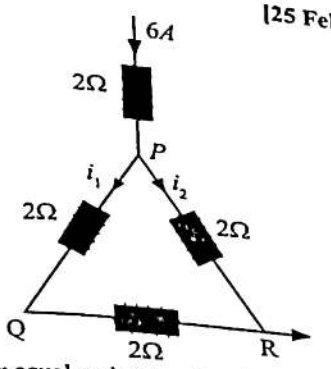
The ... resistor in the given circuit is x volt. The value of 'x' to the nearest integer is _____.

[18 March, 2021 (Shift-I)]



73. A current of 6 A enters one corner P of an equilateral triangle PQR having 3 wires of resistance 2Ω each and leaves by the corner R. The currents i_1 in ampere is_____

[25 Feb, 2021 (Shift-II)]



74. First, a set of n equal resistors of 10Ω each are connected in series to a battery of emf 20V and internal resistance 10Ω. A current I is observed to flow. Then, the n resistors are connected in parallel to the same battery. It is observed that the current is increased 20 times, then the value of n is _____.

[27 Aug, 2021 (Shift-I)]

75. Two wires of same length and thickness having specific resistances 6 Ω cm and 3 Ω cm respectively are connected in parallel. The effective resistivity is ρ Ω cm. The value of ρ to the nearest integer, is _____.

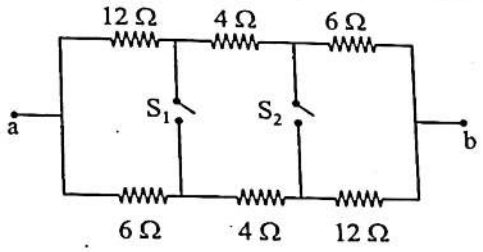
[18 March, 2021 (Shift-II)]

76. The equivalent resistance of series combination of two resistors is 's'. When they are connected in parallel, the equivalent resistance is 'p'. If $s = np$, then the minimum value for n is _____ (Round off to the nearest integer)

[17 March, 2021 (Shift-I)]

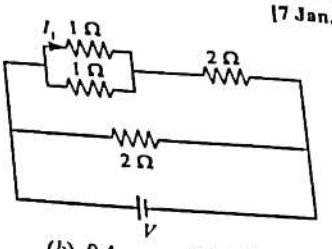
77. In the given figure switches S_1 and S_2 are in open condition. The resistance across ab when the switches S_1 and S_2 are closed is _____ Ω.

[20 July, 2021 (Shift-II)]



78. The current I, (in A) flowing through 1 Ω resistor in the following circuit is

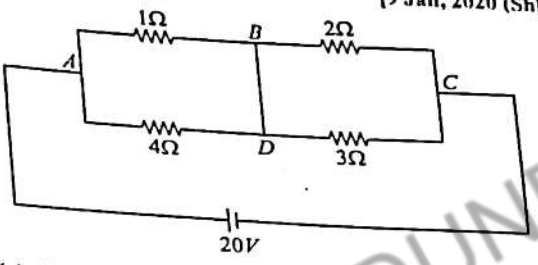
[7 Jan, 2020 (Shift-I)]



(a) 0.25 (b) 0.4 (c) 0.2 (d) 0.5

79. In the given circuit diagram, a wire is joining points B and D. The current in this wire is

[9 Jan, 2020 (Shift-I)]



(a) Zero (b) 2 A
(c) 0.4 A (d) 4 A

80. Four resistances of 15 Ω, 12 Ω, 14 Ω and 10 Ω respectively in cyclic order to form Whetstone's network. The resistance that is to be connected in parallel with the resistance of 10 Ω to balance the network is _____.

81. A metal wire of resistance 3 Ω is elongated to make a uniform wire of double its previous length. The new wire is now bent and the ends joined to make a circle. If two points on this circle make an angle 60° at the centre, the equivalent resistance between these two points will be

[9 April, 2019 (Shift-II)]

(a) $\frac{12}{5}\Omega$ (b) $\frac{5}{3}\Omega$
(c) $\frac{5}{2}\Omega$ (d) $\frac{7}{2}\Omega$

82. A uniform metallic wire has a resistance of 18 Ω and is bent into an equilateral triangle. Then, the resistance between any two vertices of the triangle is:

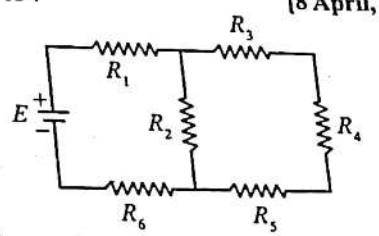
[10 Jan, 2019 (Shift-I)]

(a) 4 Ω (b) 8 Ω (c) 12 Ω (d) 2 Ω

83. In the figure shown, what is the current (in Ampere) drawn from the battery? You are given

$R_1 = 15\Omega$, $R_2 = 10\Omega$, $R_3 = 20\Omega$, $R_4 = 5\Omega$, $R_5 = 25\Omega$, $R_6 = 30\Omega$, $E = 15V$

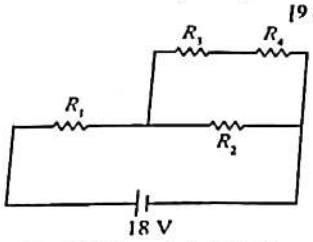
[8 April, 2019 (Shift-II)]



(a) 13/24 (b) 7/18 (c) 9/32 (d) 20/3

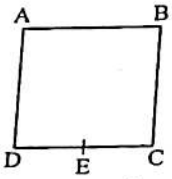
@FAKE_CRSE_X_@RAJEDUNET

84. In the given circuit the internal resistance of the 18 V cell is negligible. If $R_1 = 400\,\Omega$, $R_3 = 100\,\Omega$ and $R_4 = 500\,\Omega$ and the reading of an ideal voltmeter across R_4 is 5 V, then the value of R_2 will be
[9 Jan, 2019 (Shift-II)]



(a) 300 Ω (b) 450 Ω (c) 550 Ω (d) 230 Ω

85. A wire of resistance R is bent to form a square ABCD as shown in the figure. The effective resistance between E and C is: (E is mid-point of arm CD)
[9 April, 2019 (Shift-I)]



(a) $\frac{1}{16}R$ (b) $\frac{7}{64}R$ (c) $\frac{3}{4}R$ (d) R

Power and Heat Dissipated in Electric Circuits

86. When a potential difference V is applied across a wire of resistance R, it dissipates energy at a rate W. If the wire is cut into two halves and these halves are connected mutually parallel across the same supply, the same supply, the energy dissipation rate will become:
[30 Jan, 2024 (Shift-II)]

(a) 1/4W (b) 1/2W (c) 2W (d) 4W

87. By what percentage will the illumination of the lamp decrease if the current drops by 20%?
[31 Jan, 2024 (Shift-II)]

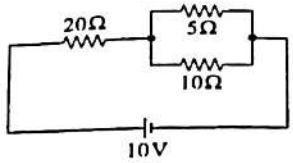
(a) 46% (b) 26%
(c) 36% (d) 56%

88. In the following circuit, the battery has an emf of 2 V and an internal resistance of $\frac{2}{3}\Omega$ The power consumption in the entire circuit is _____ W.
[31 Jan, 2024 (Shift-II)]

89. An electric bulb rated 50 W – 200 V is connected across a 100 V supply. The power dissipation of the bulb is:
[04 April, 2024 (Shift-II)]

(a) 12.5 W (b) 25 W
(c) 50 W (d) 100 W

90. The ratio of heat dissipated per second through the resistance 5 Ω and 10 Ω in the circuit given below is:
[05 April, 2024 (Shift-II)]

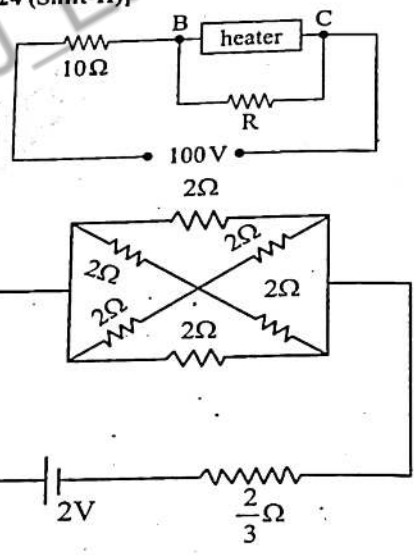


(a) 1 : 2 (b) 2 : 1
(c) 4 : 1 (d) 1 : 1

91. Water boils in an electric kettle in 20 minutes after being switched on. Using the same main supply, the length of the heating element should be ..... to ..... times of its initial length if the water is to be boiled in 15 minutes.
[08 April, 2024 (Shift-II)]

(a) increased, $\frac{3}{4}$ (b) increased, $\frac{4}{3}$
(c) decreased, $\frac{3}{4}$ (d) decreased, $\frac{4}{3}$

92. A heater is designed to operate with a power of 1000 W in a 100 V line. It is connected in combination with a resistance of 10 Ω and a resistance R, to a 100 V mains as shown in figure. For the heater to operate at 62.5 W, the value of R should be ..... Ω. **[08 April, 2024 (Shift-II)]**

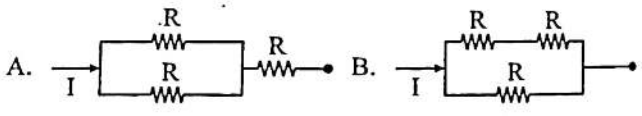


[31 Jan, 2024 (Shift-II)]

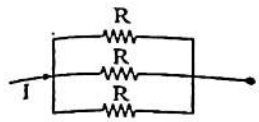
93. The H amount of thermal energy is developed by a resistor in 10s when a current of 4A is passed through it. If the current is increased to 16A, the thermal energy developed by the resistor in 10s will be:
[31 Jan, 2023 (Shift-II)]

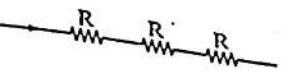
(a) H (b) 16H (c) $\frac{H}{4}$ (d) 4H

94. Different combination of 3 resistors of equal resistance R are shown in the figures.
[13 April, 2023 (Shift-I)]
The increasing order for power dissipation is:



@TAKE_CBSE_X @RAJ_EDUNET

C. 

D. 

(a) $P_A < P_B < P_C < P_D$ (b) $P_C < P_D < P_A < P_B$
(c) $P_B < P_C < P_D < P_A$ (d) $P_C < P_D < P_A < P_B$

95. Ratio of thermal energy released in two resistors R and $3R$ connected in parallel in an electric circuit is : **[29 Jan, 2023 (Shift-I)]**
(a) 3 : 1 (b) 1 : 1 (c) 1 : 3 (d) 1 : 27

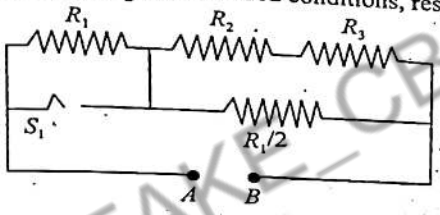
96. Two identical heater filaments are connected first in parallel and then in series. At the same applied voltage, the ratio of heat produced in same time for parallel to series will be: **[11 April, 2023 (Shift-I)]**
(a) 4 : 1 (b) 2 : 1 (c) 1 : 2 (d) 1 : 4

97. A potential V_0 is applied across a uniform wire of resistance R. The power dissipation is P_1. The wire is then cut into two equal halves and a potential of V_0 is applied across the length of each half. The total power dissipation across two wires is P_2. The ratio $P_2 : P_1$ is $\sqrt{x}$:1. The value of x is _____. **[13 April, 2023 (Shift-I)]**

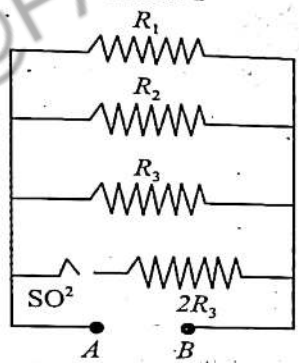
98. An electrical bulb rated 220 V, 100 W, is connected in series with another bulb rated 220 V, 60 W. If the voltage across combination is 220 V, the power consumed by the 100 W bulb will be about _____W. **[28 July, 2022 (Shift-II)]**

99. A resistor develops 300 J of thermal energy in 15 s, when a current of 2 A is passed through it. If the current increases to 3 A, the energy developed in 10 s is _____ J **[25 June, 2022 (Shift-I)]**

100. In Circuit-1 and Circuit-2 shown in the figures, $R_1 = 1\ \Omega, R_2 = 2\ \Omega$ and $R_3 = 3\Omega$.
P_1 and P_2 are the power dissipations in Circuit-1 and Circuit-2 when the switches S_1 and S_2 are in open conditions, respectively.
Q_1 and Q_2 are the power dissipations in Circuit-1 and Circuit-2 when the switches S_1 and S_2 are in closed conditions, respectively.



Circuit-1

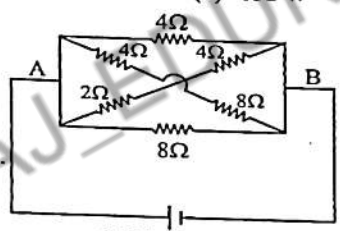


Circuit-2

Which of the following statements is(are) correct?
[JEE Adv, 2022]
(a) When a voltage source of 6 V is connected across A and B in both circuits, $P_1 < P_2$
(b) When a constant current source of 2 A is connected across A and B in both circuits, $P_1 > P_2$
(c) When a voltage source of 6 V is connected across A and B in Circuit-1, $Q_1 > P_1$
(d) When a constant current source of 2 A is connected across A and B in both circuits, $Q_2 < Q_1$

101. An electric bulb of 500 watt at 100 volt is used in a circuit having a 200 V supply. Calculate the resistance R to be connected in series with the bulb so that the power delivered by the bulb is 500 W.
[26 Aug, 2021 (Shift-II)]
(a) 20 Ω (b) 5 Ω (c) 10 Ω (d) 30 Ω

102. In the given figure, the emf of the cell is 2.2 V and if internal resistance is 0.6Ω. Calculate the power dissipated in the whole circuit : **[26 Aug, 2021 (Shift-I)]**
(a) 2.2 W (b) 0.65 W
(c) 4.4 W (d) 132 W



103. An electric appliance supplies 6000 J/min heat to the system. If the system delivers a power of 90 W. How long it would take to increase the internal energy by 2.5×10^3 J ? **[26 Aug, 2021 (Shift-I)]**
(a) 4.1×10^1 s (b) 2.4×10^3 s
(c) 2.5×10^1 s (d) 2.5×10^2 s

104. A resistor develops 500J of thermal energy in 20 s when a current of 1.5A is passed through it. If the current is increased from 1.5 A to 3 A, what will be the energy developed in 20 s. **[16 March, 2021 (Shift-II)]**
(a) 2000 J (b) 500 J
(c) 1000 J (d) 1500 J

105. A resistor dissipates 192 J of energy in 1 s when a current of 4A is passed through it. Now, when the current is doubled, the amount of thermal energy dissipated in 5 s in_____J.
[31 Aug, 2021 (Shift-II)]

106. A uniform heating wire of resistance 36 Ω is connected across a potential difference of 240 V. The wire is then cut into half and potential difference of 240 V is applied across each half separately. The ratio of power dissipation in first case to the total power dissipation in the second case would be 1 : x, where x is _____. **[1 Sep, 2021 (Shift-II)]**

107. The energy dissipated by a resistor is 10 mJ in 1 s when an electric current of 2 mA flows through it. The resistance is _____ Ω. (Round off to the Nearest Integer) **[16 March, 2021 (Shift-II)]**

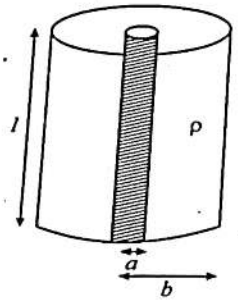
@FAKE_CBSE_X @RAJ_EDUNET

108. An electric bulb rated as 200 W at 100 V is used in a circuit having 200 V supply. The resistance 'R' that must be put in series with the bulb so that the bulb delivers the same power is_____ Ω.
[25 July, 2021 (Shift-I)]

109. In a building there are 15 bulbs of 45 W, 15 bulbs of 100 W, 15 small fans of 10 W and 2 heaters of 1kW. The voltage of electric main is 220 V. The minimum fuse capacity (rated value) of the building will be **[7 Jan, 2020 (Shift-II)]**

(a) 10 A (b) 20 A
(c) 25 A (d) 15 A

110. Model a torch battery of length l to be made up of a thin cylindrical bar of radius 'a' and a concentric thin cylindrical shell of radius 'b' filled in between with an electrolyte of resistivity ρ (see figure). If the battery is connected to a resistance of value R, the maximum Joule heating in R will take place for **[3 Sep, 2020 (Shift-I)]**

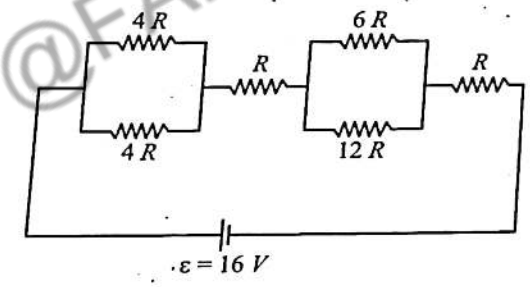


(a) $R=\frac{\rho}{\pi l}\ln\left(\frac{b}{a}\right)$ (b) $R=\frac{2\rho}{\pi l}\ln\left(\frac{b}{a}\right)$
(c) $R=\frac{\rho}{2\pi l}\ln\left(\frac{b}{a}\right)$ (d) $R=\frac{\rho}{2\pi l}\ln\left(\frac{a}{b}\right)$

111. A battery of 3.0 V is connected to a resistor dissipating 0.5 W of power. If the terminal voltage of the battery is 2.5 V, the power dissipated within the internal resistance is **[4 Sep, 2020 (Shift-I)]**

(a) 0.10 W (b) 0.072 W
(c) 0.50 W (d) 0.125 W

112. The resistive network shown below is connected to a D.C. source of 16 V. The power consumed by the network is 4 Watt. The value of R is: **[12 April, 2019 (Shift-I)]**



(a) 8Ω (b) 6Ω
(b) 16Ω (d) 1Ω

113. Two electric bulbs, rated at (25 W, 220 V) and (100 W, 220 V), are connected in series across a 220 V voltage source. If the 25 W and 100 W bulbs draw powers P_1 and P_2 respectively, then:
[12 Jan, 2019 (Shift-I)]

(a) $P_1 = 16\ W, P_2 = 4\ W$ (b) $P_1 = 16\ W, P_2 = 9\ W$
(c) $P_1 = 9\ W, P_2 = 16\ W$ (d) $P_1 = 4\ W, P_2 = 16\ W$

114. A cell of internal resistance r drives current through an external resistance R. The power delivered by the cell to the external resistance will be maximum when: **[10 Jan, 2019 (Shift-I)]**

(a) $R = 0.001\ r$ (b) $R = 1000\ r$
(c) $R = 2r$ (d) $R = r$

115. A current of 2 mA was passed through an unknown resistor which dissipated a power of 4.4 W. Dissipated power when an ideal power supply of 11 V is connected across it is :
[10 Jan, 2019 (Shift-II)]

(a) 11×10^{-5} W (b) 11×10^{-3} W
(c) 11×10^{-4} W (d) 11×10^{5} W

116. Two equal resistances when connected in series to a battery, consume electric power of 60 W. If these resistances are now connected in parallel combination to the same battery, the electric power consumed will be. **[11 Jan, 2019 (Shift-I)]**

(a) 60 W (b) 240 W (c) 120 W (d) 30 W

117. One kg of water, at 20°C, is heated in an electric kettle whose heating element has a mean (temperature averaged) resistance of 20 Ω. The rms voltage in the mains is 200V. Ignoring heat loss from the kettle, time taken for water to evaporate fully, is close to : [Specific heat of water = 4200 J/kg °C), Latent heat of water = 2260 kJ/kg]
[12 April, 2019 (Shift-II)]

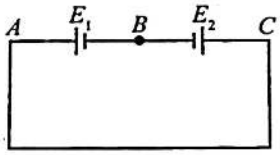
(a) 3 minutes (b) 22 minutes
(c) 10 minutes (d) 16 minutes

118. A 2 W carbon resistor is color coded with green, black, red and brown respectively. The maximum current which can be passed through this resistor is: **[10 Jan, 2019 (Shift-I)]**

(a) 20 mA (b) 100 mA
(c) 0.4 mA (d) 63 mA

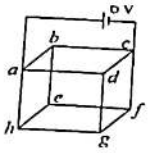
Kirchhoff's Law and Grouping of Cells

119. Two cells are connected in opposition as shown. Cell E_1 is of 8 V emf and 2Ω internal resistance; the cell E_2 is of 2 V emf and 4Ω internal resistance. The terminal potential difference of cell E_2 is:
[30 Jan, 2024 (Shift-I)]

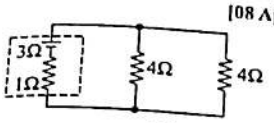


120. Twelve wires each having resistance 2Ω are joined to form a cube. A battery of 6 V emf is joined across point a and c. The voltage difference between e and f is_____ V.
[04 April, 2024 (Shift-I)]

@FAKE_JEE_X @RAJ_EDUNET

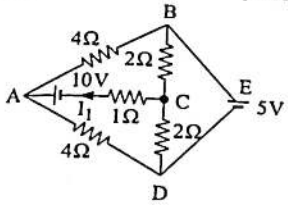


121. In the given circuit, the terminal potential difference of the cell is:
[08 April, 2024 (Shift-I)]

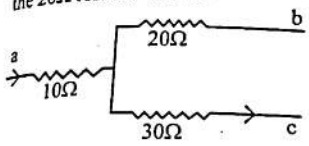


(a) 2 V (b) 4 V
(c) 1.5 V (d) 3 V

122. The current flowing through the 1 Ω resistor is $n/10$ A. The value of n is _____.
[09 April, 2024 (Shift-I)]



123. Figure shows a part of an electric circuit. The potentials at points a, b and c are 30 V, 12 V and 2 V respectively. The current through the 20Ω resistor will be.
[6 April, 2023 (Shift-II)]



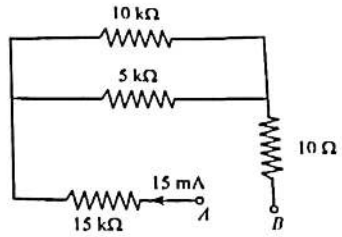
(a) 0.4 A (b) 0.2 A (c) 0.6 A (d) 1.0 A

124. Two identical cells each of emf 1.5 V are connected in parallel across a parallel combination of two resistors each of resistance 20 Ω. A voltmeter connected in the circuit measures 1.2 V. The internal resistance of each cell is:
[24 June, 2022 (Shift-I)]
(a) 2.5 Ω (b) 4 Ω (c) 5 Ω (d) 10 Ω

125. Two cells of same emf but different internal resistance r_1 and r_2 are connected in series with a resistance R. The value of resistance R, for which the potential difference across second cell is zero, is:
[25 June, 2022 (Shift-II)]
(a) $r_2 - r_1$ (b) $r_1 - r_2$
(c) r_1 (d) r_2

126. The combination of two identical cells, whether connected in series or parallel combination provides the same current through an external resistance of 2 Ω. The value of internal resistance of each cell is:
[29 June, 2022 (Shift-II)]
(a) 2 Ω (b) 4 Ω
(c) 6 Ω (d) 8 Ω

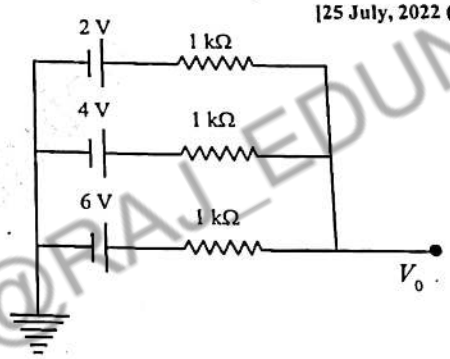
127. A current of 15 mA flows in the circuit as shown in figure. The value of potential difference between the points A and B will be:
[25 July, 2022 (Shift-II)]



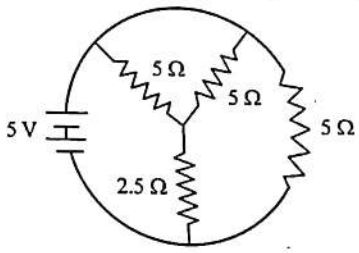
(a) 50 V (b) 75 V (c) 150 V (d) 275 V

128. Two sources of equal emfs are connected in series. This combination is connected to an external resistance R. The internal resistances of the two sources are r_1 and r_2 $(r_1 > r_2)$. If the potential difference across the source of internal resistance r_1 is zero, then the value of R will be
[27 July, 2022 (Shift-I)]
(a) $r_1 - r_2$ (b) $\frac{r_1 r_2}{r_1 + r_2}$
(c) $\frac{r_1 + r_2}{2}$ (d) $r_2 - r_1$

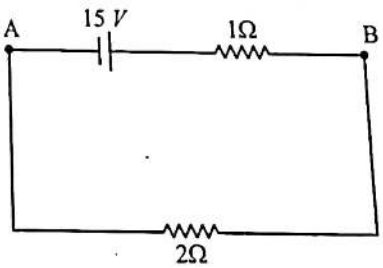
129. In the given figure, the value of V_0 will be _____ V.
[25 July, 2022 (Shift-I)]



130. The total current supplied to the circuit as shown in figure by the 5V battery is _____ A.
[25 June, 2022 (Shift-I)]

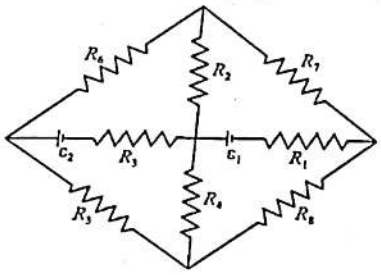


131. For the network shown below, the value of $V_B - V_A$ is _____ V.
[29 June, 2022 (Shift-I)]



@FAKE_CBSE_X @RAJ_EDUNET

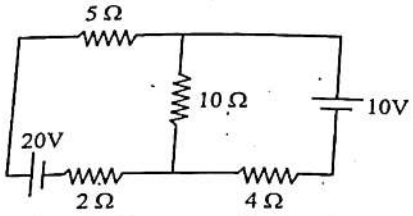
132. The figure shows a circuit having eight resistances of 1Ω each, labelled R_1 to R_8, and two ideal batteries with voltages $\varepsilon_1 = 12$ V and $\varepsilon_2 = 6$ V. **[JEE Adv, 2022]**



Which of the following statements is(are) correct?

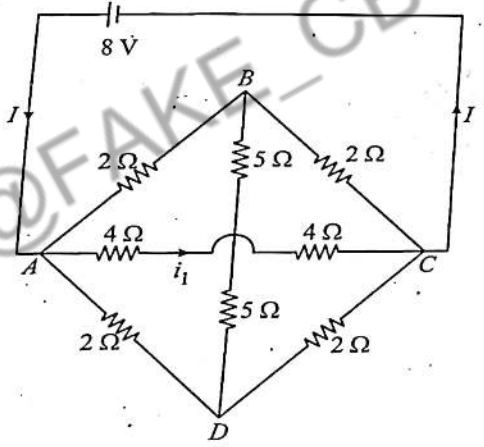
(a) The magnitude of current flowing through R_1 is 7.2 A
(b) The magnitude of current flowing through R_2 is 1.2 A
(c) The magnitude of current flowing through R_3 is 4.8 A
(d) The magnitude of current flowing through R_5 is 2.4 A

133. In the figure shown, the current in the 10 V battery is close to: **[6 Sep, 2020 (Shift-II)]**



(a) 0.71 A from positive to negative terminal
(b) 0.42 A from positive to negative terminal
(c) 0.21 A from positive to negative terminal.
(d) 0.36 A from negative to positive terminal.

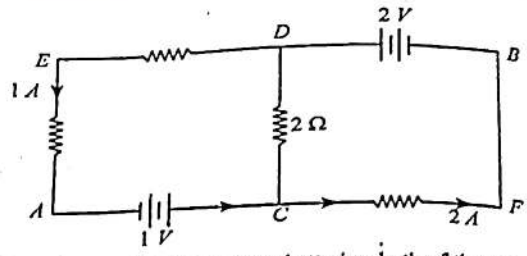
134. The value of current i_1 flowing from A to C in the circuit diagram is **[4 Sep, 2020 (Shift-II)]**



(a) 1 A (b) 4 A (c) 5 A (d) 2 A

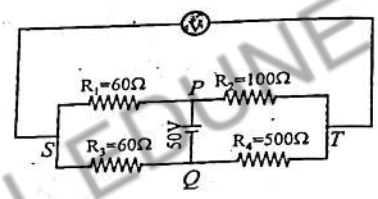
135. In the circuit, given in the figure currents in different branches and value of one resistor are shown. Then potential at point B with respect to the point A is: **[5 Sep, 2020 (Shift-II)]**

(a) +1 V (b) −1 V (c) +2 V (d) −2 V



136. The series combination of two batteries, both of the same emf 10 V, but different internal resistance of 20 Ω and 5 Ω, is connected to the parallel combination of two resistors 30 Ω and R Ω. The voltage difference across the battery of internal resistance 20 Ω is zero, the value of R (in Ω) is_____. **[8 Jan, 2020 (Shift-II)]**

137. In the balanced condition, the values of the resistances of the four arms of a Wheatstone bridge are shown in the figure below. The resistance R_3 has temperature coefficient 0.0004 °C^{-1}. If the temperature of R_3 is increased by 100 °C, the voltage developed between S and T will be _____ volt. **[JEE Adv, 2020]**



Current Measuring Instrument

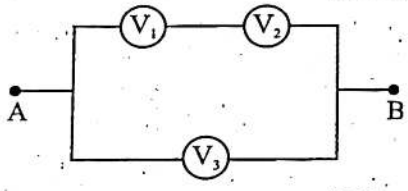
138. A wire of length 10 cm and radius $\sqrt{7} \times 10^{-4}$ m connected across the right gap of a meter bridge. When a resistance of 4.5 Ω is connected on the left gap by using a resistance box, the balance length is found to be at 60 cm from the left end. If the resistivity of the wire is $R \times 10^{-7}$ Ωm, then value of R is: **[27 Jan, 2024 (Shift-I)]**

(a) 63 (b) 70 (c) 66 (d) 35

139. Wheatstone bridge principle is used to measure the specific resistance (S_1) of given wire, having length L, radius r. If X is the resistance of wire, then specific resistance is: $S_1 = X\left(\frac{\pi r^2}{L}\right)$. If the length of the wire gets doubled then the value of specific resistance will be: **[27 Jan, 2024 (Shift-II)]**

(a) $\frac{S_1}{4}$ (b) $2S_1$ (c) $\frac{S_1}{2}$ (d) S_1

140. Three voltmeters, all having different internal resistances are joined as shown in figure. When some potential difference is applied across A and B, their readings are V_1, V_2 and V_3. Choose the correct option. **[27 Jan, 2024 (Shift-II)]**



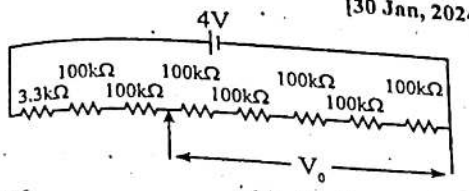
[27 Jan, 2024 (Shift-II)]

@FAKE_CBSE_X @RAJ_EDUNET

(a) $V_1 = V_2$ (b) $V_1 \neq V_3 = V_2$
(c) $V_1 + V_2 > V_3$ (d) $V_1 + V_2 = V_3$

141. A galvanometer having coil resistance 10Ω shows a full scale deflection for a current of 3mA. For it to measure a current of 8A, the value of the shunt should be: **[29 Jan, 2024 (Shift-I)]**
(a) $3 \times 10^{-3}\Omega$ (b) $4.85 \times 10^{-3}\Omega$
(c) $3.75 \times 10^{-3}\Omega$ (d) $2.75 \times 10^{-3}\Omega$

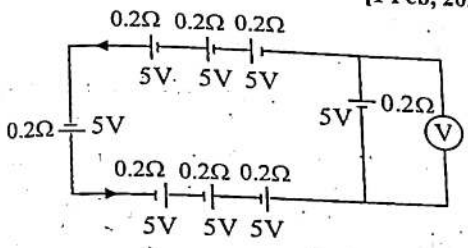
142. A potential divider circuit is shown in figure. The output voltage V_0 is **[30 Jan, 2024 (Shift-I)]**



(a) 4V (b) 2 mV
(c) 0.5 V (d) 12 mV

143. Two resistance of 100Ω and 200 Ω are connected in series with a battery of 4 V and negligible internal resistance. A voltmeter is used to measure voltage across 100 Ω resistance, which gives reading as 1 V. The resistance of voltmeter must be _____ Ω. **[30 Jan, 2024 (Shift-II)]**

144. The reading in the ideal voltmeter (V) shown in the given circuit diagram is: **[1 Feb, 2024 (Shift-I)]**



(a) 5 V (b) 10 V
(c) 0 V (d) 3 V

145. A galvanometer has a resistance of 50 Ω and it allows maximum current of 5 mA. It can be converted into voltmeter to measure upto 100 V by connecting in series a resistor of resistance **[1 Feb, 2024 (Shift-I)]**

(a) 5975Ω (b) 20050Ω
(c) 19950Ω (d) 19500Ω

146. The resistance per centimeter of a meter bridge wire is r, with X Ω resistance in left gap. Balancing length from left end is at 40 cm with 25 Ω resistance in right gap. Now the wire is replaced by another wire of 2r resistance per centimeter. The new balancing length for same settings will be at **[31 Jan, 2024 (Shift-II)]**
(a) 20 cm (b) 10 cm (c) 80 cm (d) 40 cm

147. In an ammeter, 5% of the main current passes through the galvanometer. If resistance of the galvanometer is G, the resistance of ammeter will be: **[1 Feb, 2024 (Shift-II)]**
(a) $\frac{G}{200}$ (b) $\frac{G}{199}$ (c) 199 G (d) 200 G

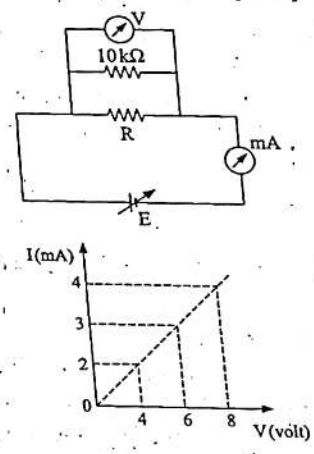
148. To measure the temperature coefficient of resistivity α of a semiconductor, an electrical arrangement shown in the figure is prepared. The arm BC is made up of the semiconductor. The experiment is being conducted at 25°C and resistance of the semiconductor arm is 3 m Ω. Arm BC is cooled at a constant rate of 2°C/s. If the galvanometer G shows no deflection after 10s, then α is: **[1 Feb, 2024 (Shift-II)]**
(a) $-2 \times 10^{-2}\,°C^{-1}$ (b) $-1.5 \times 10^{-2}\,°C^{-1}$
(c) $-1 \times 10^{-2}\,°C^{-1}$ (d) $-2.5 \times 10^{-2}\,°C^{-1}$

149. In a metre-bridge when a resistance in the left gap is 2Ω and unknown resistance in the right gap, the balance length is found to be 40 cm. On shunting the unknown resistance with 2Ω, the balance length changes by: **[1 Feb, 2024 (Shift-II)]**
(a) 22.5 cm (b) 20 cm
(c) 62.5 cm (d) 65 cm

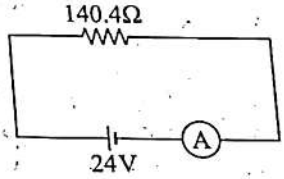
150. To measure the internal resistance of a battery, potentiometer is used. For $R = 10\ \Omega$, the balance point is observed at $\ell = 500$ cm and for $R = 1\ \Omega$ the balance point is observed at $\ell = 400$ cm. The internal resistance of the battery is approximately: **[04 April, 2024 (Shift-I)]**
(a) 0.2 Ω (b) 0.4 Ω (c) 0.1 Ω (d) 0.3 Ω

151. A galvanometer of resistance 100 Ω when connected in series with 400 Ω measures a voltage of upto 10 V. The value of resistance required to convert the galvanometer into ammeter to read upto 10 A is $x \times 10^{-2}$ Ω. The value of x is: **[05 April, 2024 (Shift-II)]**
(a) 2 (b) 800 (c) 20 (d) 200

152. To determine the resistance (R) of a wire, a circuit is designed below, The V-I characteristic curve for this circuit is plotted for the voltmeter and the ammeter readings as shown in figure. The value of R is ..... Ω. **[09 April, 2024 (Shift-II)]**



153. In the given figure an ammeter A consists of a 240 Ω coil connected in parallel to a 10 Ω shunt. The reading of the ammeter is _____ mA. **[06 April, 2024 (Shift-II)]**



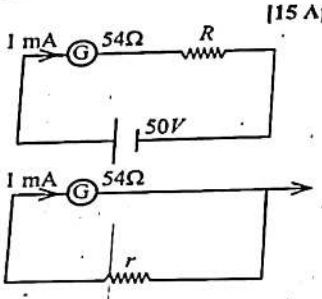
@FAKE_CBSE_X_RAJ_BHARET

154. A galvanmeter has a coil of resistance 200 Ω with a full scale deflection at 20 μA. The value of resistance to be added to use it as an ammeter of range (0–20) mA is: **[09 April, 2024 (Shift-I)]**

(a) 0.40 Ω (b) 0.20 Ω
(c) 0.50 Ω (d) 0.10 Ω

155. For designing a voltmeter of range 50 V and an ammeter of range 10 mA using a galvanometer which has a coil of resistance 54Ω showing a full scale deflection for 1 mA as in figure.

[15 April, 2023 (Shift-I)]



(A) for voltmeter $R \approx 50\ k\Omega$
(B) for ammeter $r \approx 0.2\ \Omega$
(C) for ammeter $r \approx 6\ \Omega$
(D) for voltmeter $R \approx 5\ k\Omega$
(E) for voltmeter $R \approx 500\ \Omega$

Choose the correct answer from the options given below:

(a) (C) and (E) (b) (C) and (D)
(c) (A) and (C) (d) (A) and (B)

156. Given below are two statements: One is labelled as Assertion (A) and the other is labelled as Reason (R).

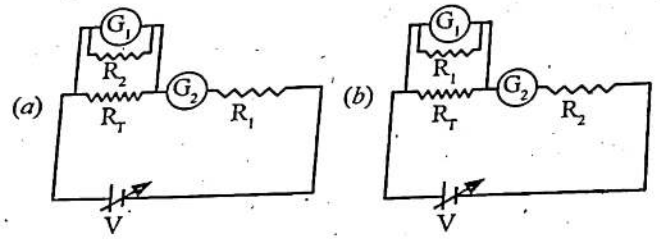
Assertion (A): For measuring the potential difference across a resistance of 600Ω, the voltmeter with resistance 1000Ω will be preferred over voltmeter with resistance 4000Ω.

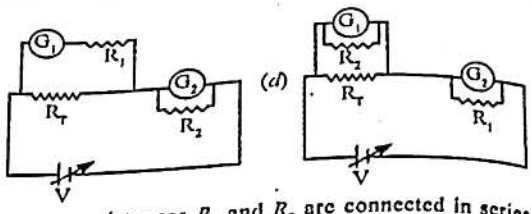
Reason (R): Voltmeter with higher resistance will draw smaller current than voltmeter with lower resistance.

In the light of the above statements, choose the most appropriate answer from the options given below. **[1 Feb, 2023 (Shift-II)]**

(a) (A) is not correct but (R) is correct
(b) Both (A) and (R) are correct and (R) is the correct explanation of (A)
(c) Both (A) and (R) are correct but (R) is not the correct explanation of (A)
(d) (A) is correct but R is not correct

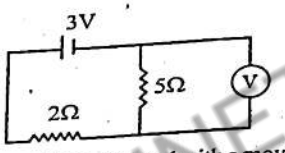
157. A student is provided with a variable voltage source V, a test resistor $R_T = 10\Omega$, two identical galvanometers G_1 and G_2 and two additional resistors, $R_1 = 10M\Omega$ and $R_2 = 0.001\Omega$. For conducting an experiment to verify ohms law, the most suitable circuit is: **[6 April, 2023 (Shift-II)]**





158. When two resistances R_1 and R_2 are connected in series and introduced into the left gap of a meter bridge and a resistance of 10Ω is introduced into the right gap, a null point is found at 60 cm from the left side. When R_1 and R_2 are connected in parallel and introduced into the left gap, a resistance of 3Ω is introduced into the right-gap to get null point at 40 cm from left the end. The product of $R_1 R_2$ is _____ Ω^2 **[29 Jan, 2023 (Shift-II)]**

159. As shown in the figure, the voltmeter reads 2V across 5Ω resistor. The resistance of the voltmeter is _____Ω. **[6 April, 2023 (Shift-II)]**



160. When a resistance of 5Ω is shunted with a moving coil galvanometer, it shows a full scale deflection for a current of 250 mA, however when 1050Ω resistance is connected with it in series, it gives full scale deflection for 25 volt. The resistance of galvanometer is _____ Ω. **[13 April, 2023 (Shift-I)]**

161. In a metre bridge experiment the balance point is obtained if the gaps are closed by 2Ω and 3Ω. A shunt of XΩ is added to 3Ω resistor to shift the balancing point by 22.5 *cm*. The value of X is _____. **[29 Jan, 2023 (Shift-I)]**

162. A null point is found at 200 cm in potentiometer when cell in secondary circuit is shunted by 5Ω. When a resistance of 15Ω is used for shunting null point moves to 300 cm. The internal resistance of the cell is _____. Ω. **[29 Jan, 2023 (Shift-II)]**

163. A 72Ω galvanometer is shunted by a resistance of 8Ω. The percentage of the total current which passes through the galvanometer is: **[27 June, 2022 (Shift-I)]**

(a) 0.1% (b) 10% (c) 25% (d) 0.25%

164. A teacher in his physics laboratory allotted an experiment to determine the resistance (G) of a galvanometer. Students took the observations for $\frac{1}{3}$ deflection in the galvanometer. Which of the below is true for measuring value of G? **[25 June, 2022 (Shift-I)]**

(a) $\frac{1}{3}$ deflection method cannot be used for determining the resistance of the galvanometer.
(b) $\frac{1}{3}$ deflection method can be used and in this case the G equals to twice the value of shunt resistance(s).
(c) $\frac{1}{3}$ deflection method can be used and in this case, the G equals to three times the value of shunt resistance(s).
(d) $\frac{1}{3}$ deflection method can be used and in this case, the G value equals to the shunt resistance(s).

@JEE_CBSE_X@RAVEDU.NET

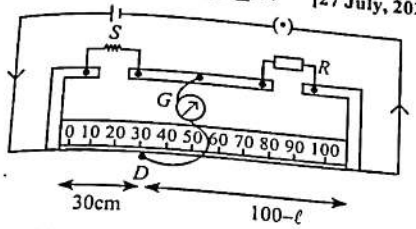
166. A 72Ω galvanometer is shunted by a resistance of 8Ω. The percentage of the total current which passes through the galvanometer is: **[27 June, 2022 (Shift-I)]**

(a) 0.1% (b) 10%
(c) 25% (d) 0.25%

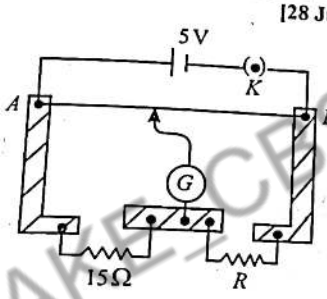
167. If n represents the actual number of deflections in a converted galvanometer of resistance G and shunt resistance S. Then the total current I when its figure of merit is K will be **[25 June, 2022 (Shift-II)]**

(a) $\frac{KS}{(S+G)}$ (b) $\frac{(G+S)}{nKS}$
(c) $\frac{nKS}{(G+S)}$ (d) $\frac{nK(G+S)}{S}$

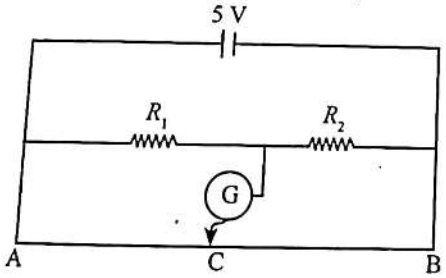
168. In a meter bridge experiment, for measuring unknown resistance 'S', the null point is obtained at a distance 30 cm from the left side as shown at point D. If R is 5.6 kΩ, then the value of unknown resistance 'S' will be _____ Ω. **[27 July, 2022 (Shift-I)]**



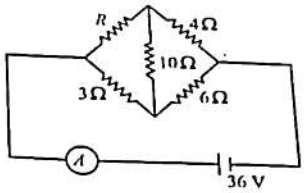
169. A meter bridge setup is shown in the figure. It is used to determine an unknown resistance R using a given resistor of 15Ω. The galvanometer (G) shows null deflection when tapping key is at 43 cm mark from end A. If the end correction for end A is 2 cm. Then the determined value of R will be _____ Ω. **[28 June, 2022 (Shift-I)]**



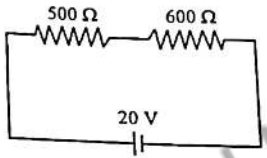
169. In the given figure of meter bridge experiment, the balancing length AC corresponding to null deflection of the galvanometer is 40 cm. The balancing length, if the radius of the wire AB is doubled, will be _____ cm. **[27 July, 2022 (Shift-II)]**



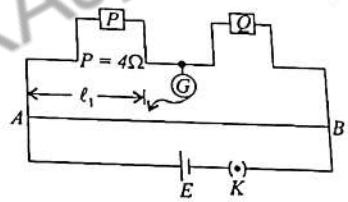
170. Current measured by the ammeter (A) in the reported circuit when no current flows through 10 resistance, will be _____ A. **[28 June, 2022 (Shift-I)]**



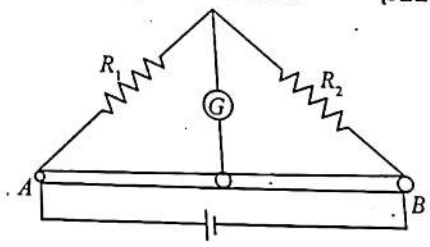
171. Two resistors are connected in series across a battery as shown in figure. If a voltmeter of resistance 2000 Ω is used to measure the potential difference across 500 Ω resister, the reading of the voltmeter will be _____ V. **[29 June, 2022 (Shift-II)]**



172. Resistances are connected in a meter bridge circuit as shown in the figure. The balancing length ℓ_2 is 40 cm. Now an unknown resistance x is connected in series with P and new balancing length is found to be 80cm measured from the same end. Then the value of x will be _____ Ω. **[26 July, 2022 (Shift-I)]**



173. Two resistances $R_1 = X\ \Omega$ and $R_2 = 1\ \Omega$ are connected to a wire AB of uniform resistivity, as shown in the figure. The radius of the wire varies linearly along its axis from 0.2 mm at A to 1 mm at B. A galvanometer (G) connected to the center of the wire, 50 cm from each end along its axis, shows zero deflection when A and B are connected to a battery. The value of x is **[JEE Adv, 2022]**



174. For full scale deflection of total 50 divisions, 50 mV voltage is required in galvanometer. The resistance of galvanometer if its current sensitivity is 2 div/mA will be: **[27 Aug, 2021 (Shift-II)]**

(a) 2Ω (b) 4Ω
(c) 1Ω (d) 5Ω

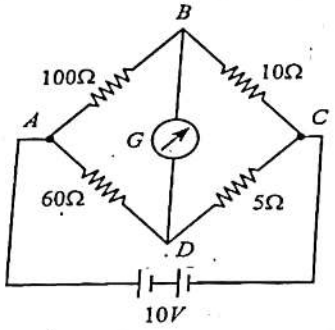
@TAKE_CBSE_X @RAJ_BRUNET

175. Consider a galvanometer shunted with 5 Ω resistance and 2% of current passes through it. What is the resistance of the given galvanometer? **[31 Aug, 2021 (Shift-I)]**

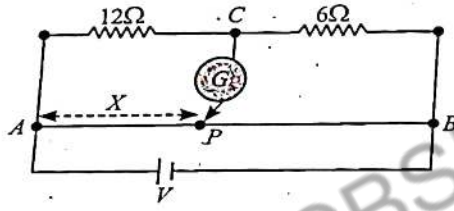
(a) 300 Ω (b) 344 Ω
(c) 226 Ω (d) 245 Ω

176. The four arms of a Wheatstone bridge have resistances as shown in the figure. A galvanometer of 15Ω resistance is connected across BD. Calculate the current through the galvanometer when a potential difference of 10 V is maintained across AC. **[17 March, 2021 (Shift-II)]**

(a) 4.87 μA (b) 2.44 mA
(c) 4.87 mA (d) 2.44 μA

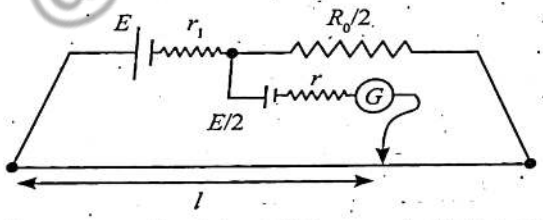


177. Consider a 72 cm long wire AB as shown in the figure. The galvanometer jockey is placed at P on AB at a distance x cm from A. The galvanometer shows zero deflection.



The value of x, to nearest integer, is _____ **[18 March, 2021 (Shift-II)]**

178. In order to measure the internal resistance r_1 of a cell of emf E, a meter bridge of wire resistance $R_0 = 50\ \Omega$, a resistance $R_0/2$, another cell of emf E/2 (internal resistance r) and a galvanometer G are used in a circuit, as shown in the figure. If the null point is found at $l = 72$ cm, then the value of $r_1 = \ldots\Omega$. **[JEE Adv, 2021]**



179. A galvanometer of resistance G is converted into a voltmeter of range 0 – 1V by connecting a resistance R_1 in series with it. The additional resistance that should be connected in series with R_1 to increase the range of the voltmeter to 0 – 2V will be: **[5 Sep, 2020 (Shift-I)]**

(a) $R_1 + G$. (c) G (b) R_1 (d) $R_1 - G$

180. Two resistors 400Ω and 800Ω are connected in series across a 6 V battery. The potential difference measured by a voltmeter of 10 kΩ across 400Ω resistor is close to: **[3 Sep, 2020 (Shift-II)]**

(a) 2 V (b) 2.05 V
(c) 1.95 V (d) 1.8 V

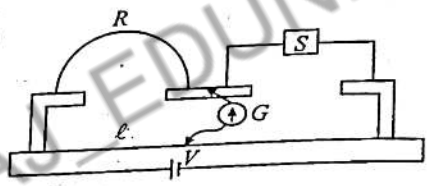
181. A galvanometer is used in laboratory for detecting the null point in electrical experiments. If, on passing a current of 6mA it produces a deflection of 2°, its figure of merit is close to: **[5 Sep, 2020 (Shift-II)]**

(a) 666° A/div. (b) 6×10^{-3} A/div
(c) 333° A/div. (d) 3×10^{-3} A/div

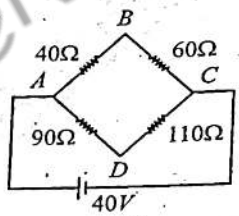
182. A galvanometer having a coil resistance 100 Ω gives a full scale deflection when a current of 1 mA is passed through it. What is the value of the resistance which can convert this galvanometer into a voltmeter giving full scale deflection for a potential difference of 10 V. **[8 Jan, 2020 (Shift-II)]**

(a) 9.9 kΩ (b) 7.9 kΩ (c) 10 kΩ (d) 8.9 kΩ

183. In a meter bridge experiment S is a standard resistance. R is a resistance wire. It is found that balancing length is $\ell = 25$ cm. If R is replaced by a wire of half-length and half diameter that of R of same material, then the balancing distance ℓ (in cm) will now be **[9 Jan, 2020 (Shift-II)]**



184.



Four resistance 40Ω, 60Ω, 90Ω, and 110Ω, make the arms of a quadrilateral ABCD. Across AC is a battery of emf 40 V and internal resistance negligible. The potential difference across BD in V is _____ **[4 Sep, 2020 (Shift-II)]**

185. The resistance of a galvanometer is 50 ohm and the maximum current which can be passed through it is 0.002 A. What resistance must be connected to it in order to convert it into an ammeter of range 0 – 0.5 A? **[9 April, 2019 (Shift-II)]**

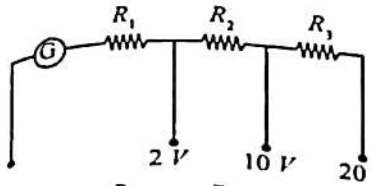
(a) 0.2 ohm (b) 0.002 ohm
(c) 0.02 ohm (d) 0.5 ohm

186. A moving coil galvanometer has resistance 50Ω and it indicates full deflection at 4mA current. A voltmeter is made using this galvanometer and a 5 kΩ resistance. The maximum voltage, that can be measured using this voltmeter, will be close to: **[9 April, 2019 (Shift-I)]**

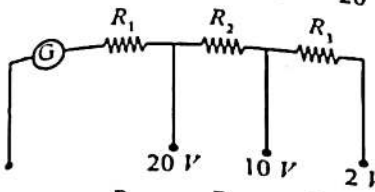
(a) 15 V (b) 20 V (c) 10 V (d) 40 V

187. A galvanometer of resistance 100 Ω has 50 divisions on its scale and has sensitivity of 20μA/ division. It is to be converted to a voltmeter with three ranges, of 0 – 2 V, 0 – 10 V and 0-20 V. The appropriate circuit to do so is: **[12 April, 2019 (Shift-I)]**

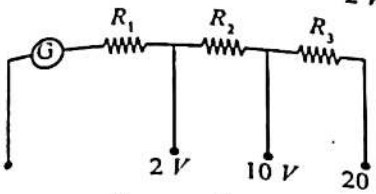
@RAKE_CBSE X @RAJ_EDUNE

(a) 

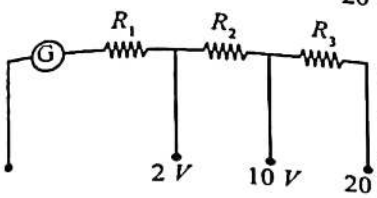
$R_1 = 2000\ \Omega$
$R_2 = 8000\ \Omega$
$R_3 = 10000\ \Omega$

(b) 

$R_1 = 19900\ \Omega$
$R_2 = 9900\ \Omega$
$R_3 = 1900\ \Omega$

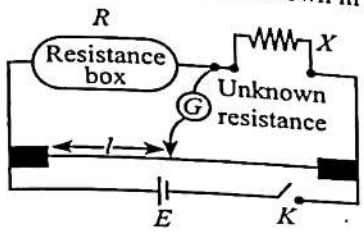
(c) 

$R_1 = 1900\ \Omega$
$R_2 = 8000\ \Omega$
$R_3 = 10000\ \Omega$

(d) 

$R_1 = 1900\ \Omega$
$R_2 = 9900\ \Omega$
$R_3 = 19900\ \Omega$

188. In a meter bridge experiment, the circuit diagram and the corresponding observation table are shown in figure.



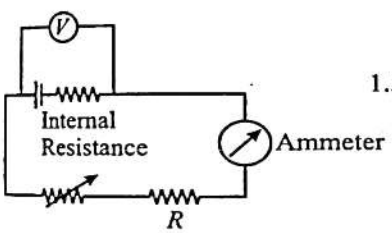
Sl. No.	R (Ω)	l (cm)
1.	1000	60
2.	100	13
3.	10	1.5
4.	1	1.0

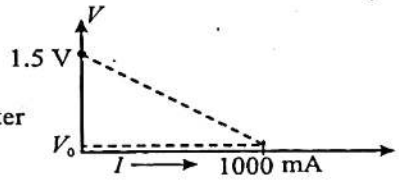
Which of the readings is inconsistent? **[10 April, 2019 (Shift-I)]**

(a) 4 (b) 3 (c) 2 (d) 1

189. To verify Ohm's law, a student connects the voltmeter across the battery as, shown in the figure. The measured voltage is plotted as a function of the current, and the following graph is obtained. If V_0 is almost zero, identify the correct statement

[12 April, 2019 (Shift-I)]





(a) The value of the resistance R is 1.5 Ω

(b) The emf of the battery is 1.5 V and the value of R is 1.5 Ω

(c) The emf of the battery is 1.5 V and its internal resistance is 1.5 Ω

(d) The potential difference across the battery is 1.5 V when it sends a current of 1000 mA

190. An ideal battery of 4 V and resistance R are connected in series in the primary circuit of a potentiometer of length 1 m and resistance 5 Ω. The value of R, to give a difference of 5 mV across 10 cm of potentiometer wire, is: **[12 Jan, 2019 (Shift-I)]**

(a) 490 Ω (b) 480 Ω (c) 395 Ω (d) 495 Ω

191. A moving coil galvanometer allows a full scale current of 10^{-4} A. A series resistance of 2 MΩ is required to convert the above galvanometer into a voltmeter of range 0 – 5 V. Therefore the value of shunt resistance required to convert the above galvanometer into a ammeter of range 0–10 mA is: **[10 April, 2019 (Shift-I)]**

(a) 200 Ω (b) 100 Ω (c) 10 Ω (d) 500 Ω

192. A moving coil galvanometer, having a resistance G, produces full scale deflection when a current I_g flows through it. This galvanometer can be converted into (i) an ammeter of range 0 to I_0 ($I_0 > I_g$) by connecting a shunt resistance R_A to it and (ii) into a voltmeter of range 0 to $V (V = GI_0)$ by connecting a series resistance R_V to it. Then, **[12 April, 2019 (Shift-II)]**

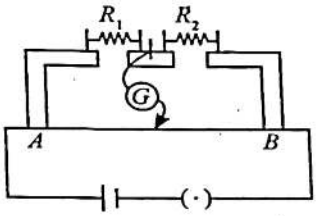
(a) $R_A R_V = G^2 \left(\frac{I_g}{I_0 - I_g}\right)$ and $\frac{R_A}{R_V} = \left(\frac{I_0 - I_g}{I_g}\right)^2$

(b) $R_A R_V = G^2$ and $\frac{R_A}{R_V} = \left(\frac{I_g}{I_0 - I_g}\right)^2$

(c) $R_A R_V = G^2$ and $\frac{R_A}{R_V} = \frac{I_g}{I_0 - I_g}$

(d) $R_A R_V = G^2 \left(\frac{I_0 - I_g}{I_g}\right)$ and $\frac{R_A}{R_V} = \left(\frac{I_g}{I_0 - I_g}\right)^2$

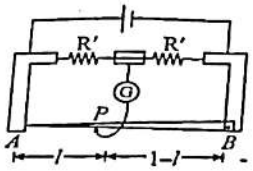
193. In the experimental setup of metre bridge shown in the figure, the null point is obtained at a distance of 40 cm from A. If a 10Ω resistor is connected in series with R_1, the null point shifts by 10 cm. The resistance that should be connected in parallel with $(R_1 + 10)\Omega$ such that the null point shifts back to its initial position is _____ :



(a) 20Ω (b) 40Ω (c) 60Ω (d) 30Ω

194. In a meter bridge, the wire of length 1 m has a non-uniform cross-section such that the variation $\frac{dR}{dl}$ of its resistance R with length l is $\frac{dR}{dl} \propto \frac{1}{\sqrt{l}}$. Two equal resistances are connected as shown in the figure. The galvanometer has zero deflection when the jockey is a point P. What is the length AP? **[12 Jan, 2019 (Shift-I)]**

@FAKE_CBSE X @RAJ_EDUNET



(a) 0.2 m (b) 0.3 m (c) 0.25 m (d) 0.35 m

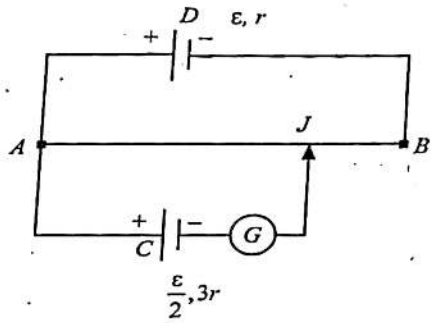
195. A galvanometer, whose resistance is 50 ohm, has 25 divisions in it. When a current of 4×10^{-4} A passes through it, its needle (pointer) deflects by one division. To use this galvanometer as a voltmeter of range 2.5 V, it should be connected to a resistance of :

[12 Jan, 2019 (Shift-II)]

(a) 250 ohm (b) 200 ohm (c) 6200 ohm (d) 6250 ohm

196. A potentiometer wire AB having length L and resistance $12r$ is joined to a cell D of emf ε and internal resistance r. A cell C having emf $\varepsilon/2$ and internal resistance $3r$ is connected. The length AJ at which the galvanometer as shown in figure shows no deflection is:

[10 Jan, 2019 (Shift-I)]



(a) $\frac{11}{12}L$ (b) $\frac{11}{24}L$ (c) $\frac{13}{24}L$ (d) $\frac{5}{12}L$

197. A galvanometer having a resistance of 20Ω and 30 divisions on both sides has figure of merit 0.005 ampere /division. The resistance that should be connected in series such that it can be used as a voltmeter upto 15 volt is:

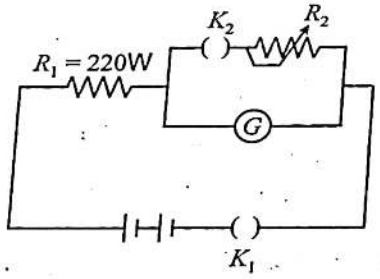
[11 Jan, 2019 (Shift-II)]

(a) 100Ω (b) 120Ω (c) 80Ω (d) 125Ω

198. The galvanometer deflection, when key K_1 is closed but K_2 is open, equals θ_0 (see figure). On closing K_2 also and adjusting R_2 to 5 Ω, the deflection in galvanometer becomes $\frac{\theta_0}{5}$. The resistance of the galvanometer is, then, given by

[Neglect the internal resistance of battery]:

[12 Jan, 2019 (Shift-I)]



(a) 5 Ω (b) 22 Ω (c) 25 Ω (d) 12 Ω

199. In a Wheatstone bridge (see figure) Resistance P and Q are approximately equal. When $R = 400\ \Omega$, the bridge is balanced. On interchanging P and Q, the value of R, for balance is 405 Ω. The value of X is close to: **[11 Jan, 2019 (Shift-I)]**

(a) 401.5 ohm (b) 404.5 ohm (c) 403.5 ohm (d) 402.5 ohm

200. The resistance of the meter bridge AB in given figure is 4Ω. With a cell of emf $\varepsilon = 005$ V and rheostat resistance $R_h = 2\ \Omega$ the null point is obtained at some point J. When the cell is replaced by another one of emf $\varepsilon = \varepsilon_2$ the same null point J is found for $R_h = 6\ \Omega$. The emf ε_2 is: **[11 Jan, 2019 (Shift-I)]**

(a) 0.4 V (b) 0.3 V (c) 0.6 V (d) 0.5 V

201. Two identical moving coil galvanometer have 10 Ω resistance and full scale deflection at 2 μA current. One of them is converted into a voltmeter of 100 mV full scale reading and the other into an Ammeter of 1 mA full scale current using appropriate resistors. These are then used to measure the voltage and current in the Ohm's law experiment with R = 1000 Ω resistor by using an ideal cell. Which of the following statements is/are correct? **[JEE Adv, 2019]**

(a) The measured value of R will be $978\ \Omega < R < 982\ \Omega$

(b) The resistance of the Voltmeter will be 100 kΩ

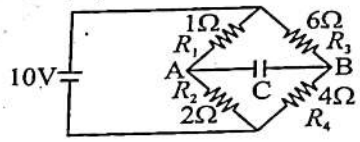
(c) The resistance of the Ammeter will be 0.02 Ω (round off to 2nd decimal place)

(d) If the ideal cell is replaced by a cell having internal resistance of 5 Ω then the measured value of R will be more than 1000 Ω

RC Circuit

202. The charge accumulated on the capacitor connected in the following circuit is ____μC

(Given C = 150 μF)

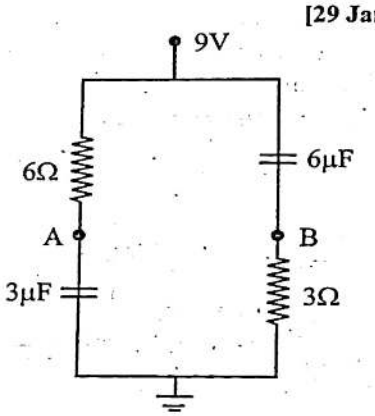


[27 Jan, 2024 (Shift-I)]

203. A 16Ω wire is bend to form a square loop. A 9V battery with internal resistance 1Ω is connected across one of its sides. If a 4μF capacitor is connected across one of its diagonals, the energy stored by the capacitor will be $\frac{x}{2}$ μJ. where $x =$ ____. **[29 Jan, 2024 (Shift-I)]**

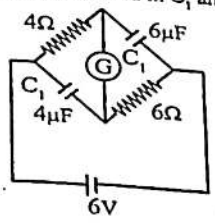
204. In the given figure, the charge stored in 6μF capacitor, when points A and B are joined by a connecting wire is _____μC.

[29 Jan, 2024 (Shift-II)]



@TAKE CBSE X @RAJ EDUNET

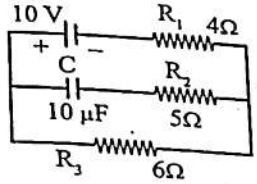
205. A galvanometer (G) of 2Ω resistance is connected in the given circuit. The ratio of charge stored in C_1 and C_2 is:



[1 Feb, 2024 (Shift-II)]

(a) $\frac{2}{3}$ (b) $\frac{3}{2}$ (c) 1 (d) $\frac{1}{2}$

206. In an electrical circuit drawn below the amount of charge stored in the capacitor is _____ μC.



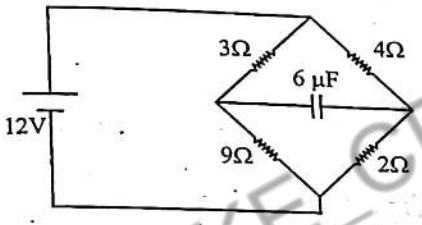
[1 Feb, 2024 (Shift-II)]

207. The electric field between the two parallel plates of a capacitor of 1.5 μF capacitance drops to one third of its initial value in 6.6 μs when the plates are connected by a thin wire. The resistance of this wire is ..... Ω. (Given, log 3 = 1.1)

[05 April, 2024 (Shift-I)]

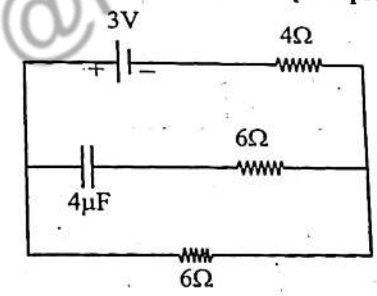
208. In the circuit shown, the energy stored in the capacitor is n μJ. The value of n is_____.

[13 April, 2023 (Shift-II)]



209. In the network shown below, the charge accumulated in the capacitor in steady state will be :

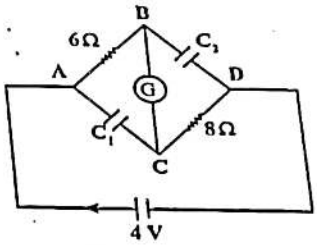
[13 April, 2023 (Shift-II)]



(a) 7.2 μC (b) 4.8 μC (c) 10.3 μC (d) 12 μC

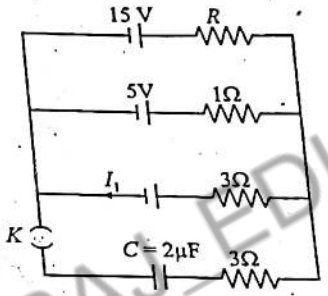
210. In this figure the resistance of the coil of galvanometer G is 2 Ω. The emf of the cell is 4 V. The ratio of potential difference across C_1 and C_2 is:

[8 April, 2023 (Shift-I)]



(a) 1 (b) $\frac{4}{5}$ (c) $\frac{3}{4}$ (d) $\frac{5}{4}$

211. In a circuit shown in the figure, the capacitor C is initially uncharged and the key K is open. In this condition, a current of 1A flows through the 1Ω resistor. The key is closed at time $t = t_0$. Which of the following statements is are correct? [JEE Adv, 2023]
[Given: $e^{-1} = 0.36$]

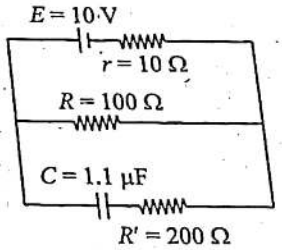


(a) The value of the resistance R is 3Ω.
(b) For $t < t_0$, the value of current I_1 is 2A.
(c) At $t = t_0 + 7.2$ μs, the current in the capacitor is 0.6A.
(d) For $t \to \infty$, the charge on the capacitor is 12 μC.

212. A capacitor is discharging through a resistor R. Consider in time t_1 the energy stored in the capacitor reduces to half of its initial value and in time t_2, the charge stored in the capacitor reduces to half of its initial value and in time t_2, the charge stored reduces to one eighth of its initial value. The ratio t_1/t_2 will be [29 June, 2022 (Shift-II)]

(a) 1/2 (b) 1/3 (c) 1/4 (d) 1/6

213. As shown in the figure, in steady state, the charge stored in the capacitor is _____ × 10^{-6} C. [27 July, 2022 (Shift-II)]



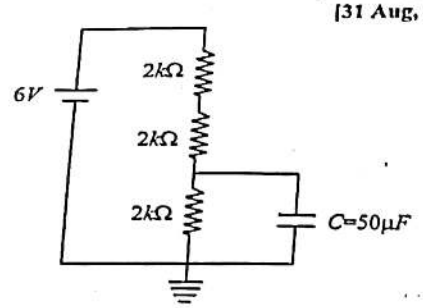
214. A capacitor is connected to a 20 V battery through a resistance of 10Ω. It is found that the potential difference across the capacitor rises to 2 V in 1 μs. The capacitance of the capacitor is _____ μF

Given $\ln\left(\frac{10}{9}\right) = 0.105$ [1 Sep, 2021 (Shift-II)]

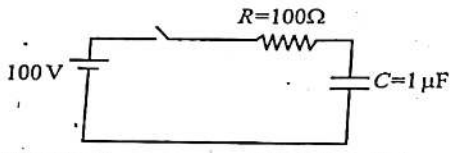
(a) 1.85 (b) 0.95 (c) 0.105 (d) 9.52

@FAKE_CBSE_X@RAJ_EDUNET

215. A capacitor of 50 μF is connected in a circuit as shown in figure. The charge on the upper plate of the capacitor is_____ μC.
[31 Aug, 2021 (Shift-I)]

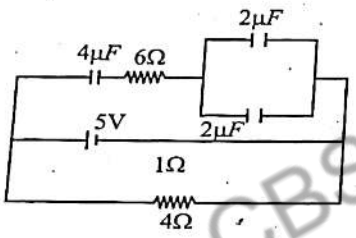


216. A capacitor of capacitance $C = 1\mu F$ is suddenly connected to a battery of 100 volt through a resistance $R = 100\ \Omega$. The time taken for the capacitor to be charged to get 50 V is:
[Take In 2 = 0.69] **[27 July, 2021 (Shift-I)]**



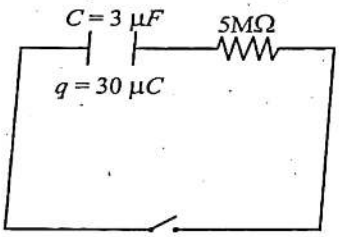
(a) 3.33×10^{-4} s (b) 1.44×10^{-4} s
(c) 0.30×10^{-4} s (d) 0.69×10^{-4} s

217. Calculate the amount of charge on capacitor of $4\mu F$. The internal resistance of battery is 1Ω. **[27 Aug, 2021 (Shift-I)]**



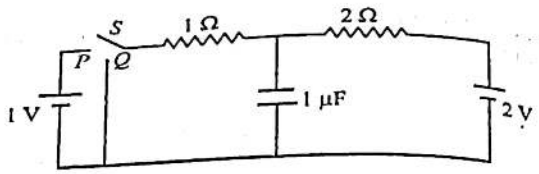
(a) 16 μC (b) zero
(c) 4μC (d) 8μC

218. The circuit shown in the figure consists of a charged capacitor of capacity 3μF and a charge of 30 μC. At time $t = 0$, when the key is closed, the value of current flowing through the 5MΩ resistor is 'x' μA.
[18 March, 2021 (Shift-I)]



The value of 'x' to the nearest integer is _____.

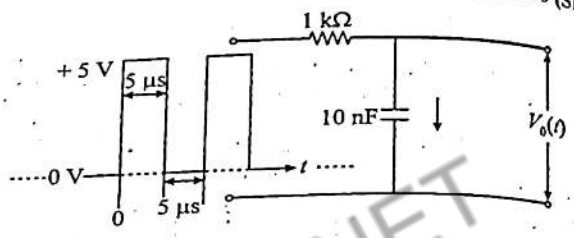
Comprehension (Q.219 to 220) In the circuit shown below, the switch S is connected to position P for a long time so that the charge on the capacitor becomes q_1 μC. Then S is switched to position Q. After a long time, the charge on the capacitor is q_2 μC. **[JEE Adv, 2021]**

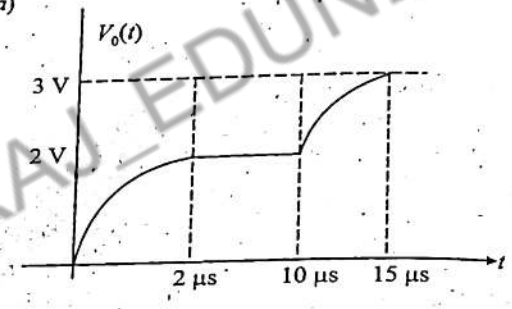


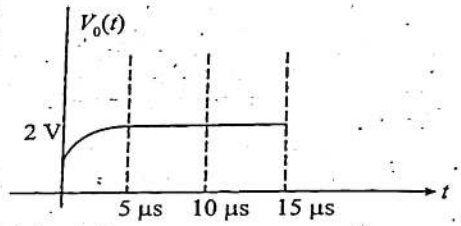
219. The magnitude of q_1 is _____.

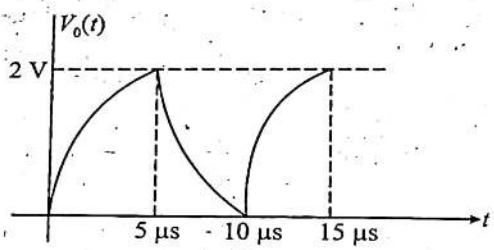
220. The magnitude of q_2 is _____.

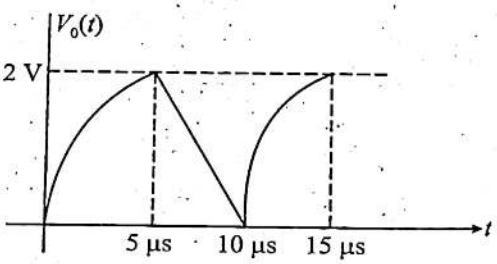
221. For the given input voltage waveform $V_{in}(t)$, the output voltage waveform $V_o(t)$, across the capacitor is correctly depicted by
[6 Sep, 2020 (Shift-I)]



(a)


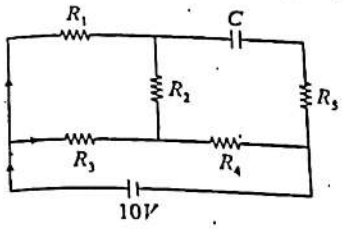
(b)


(c)


(d)


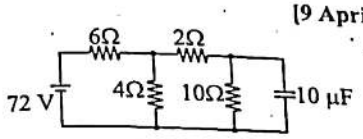
@FIKE_CBSE X @RAJ_EDUNET

222. An ideal cell of emf 10 V is connected in circuit shown in figure. Each resistance is 2 Ω. The potential difference (in V) across the capacitor when it is fully charged is _____. [2 Sep, 2020 (Shift-II)]



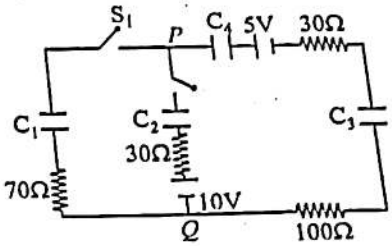
223. A 60 pF capacitor is fully charged by a 20 V supply. It is then disconnected from the supply and is connected to another uncharged 60pF capacitor in parallel. The electrostatic energy that is lost in this process by the time the charge is redistributed between them is (in nJ)_____. [7 Jan, 2020 (Shift-II)]

224. Determine the charge on the capacitor in the following circuit: [9 April, 2019 (Shift-I)]



(a) 200 μC (b) 60 μC
(c) 10 μC (d) 2 μC

225. In the circuit shown, initially there is no charge on capacitors and keys S1 and S2 are open. The values of the capacitors are C1 = 10 μF, C2 = 30 μF and C3 = C4 = 80 μF. [JEE Adv, 2019]



Which of the statements is/are correct?

(a) The keys S_1 is kept closed for long time such that capacitors are fully charged. Now key S_2 is closed, at this time, the instantaneous current across 30 Ω resistor (between points P and Q) will be 0.2 A (round off to 1st decimal place)

(b) If key S_1 is kept closed for long time such that capacitors are fully charged, the voltage difference between points P and Q will be 10 V

(c) At time t = 0, the key S_1 is closed, the instantaneous current in the closed circuit will be 25 mA

(d) If key S_1 is kept closed for long time such that capacitors are fully charged, the voltage across the capacitors C_1 will be 4V

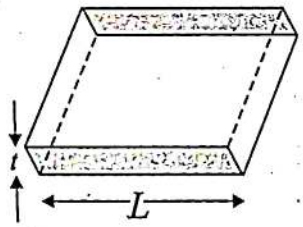
JEE-Advanced

Microscopic Analysis, Drift Velocity, Ohm's Law, Conductivity

Single Correct

1. A current of 5 A passes through a copper conductor (resistivity = 1.7×10^{8} Ω-m) of radius of cross-section 5 mm. Find the mobility of the charges, if their drift velocity is 1.1×10^{-3} m/s. **(JEE Adv. 2015)**
   (a) 1.5 m²/V-s
   (b) 1.3 m²/V-s
   (c) 1.0 m²/V-s
   (d) 1.8 m²/V-s

2. Consider a thin square sheet of side L and thickness t, made of a material of resistivity ρ. The resistance between two opposite faces, shown by the shaded areas in the figure is **(IIT-JEE 2010)**



   (a) Directly proportional to L
   (b) Directly proportional to t
   (c) Independent of L
   (d) Independent of t

3. A steady current flows in a metallic conductor of non-uniform cross-section. The quantity/quantities constant along the length of the conductor is/are **(IIT-JEE 1997)**
   (a) Current, electric field and drift speed
   (b) Drift speed only
   (c) Current and drift speed
   (d) Current only

4. A piece of copper and another of germanium are cooled from room temperature to 80K. The resistance of **(IIT-JEE 1988)**
   (a) Each of them increases
   (b) Each of them decreases
   (c) Copper increases and germanium decreases
   (d) Copper decreases and germanium increases

True/False

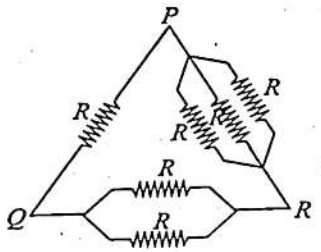
5. Electrons in a conductor have no motion in the absence of a potential difference across it. **(IIT-JEE 1982)**

@TAKE_CBSE_X @RAJ_EDUNET

Series and Parallel Combination of Resistance

Single Correct

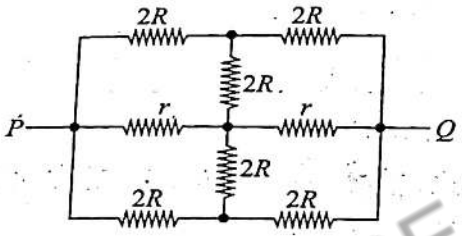
6. Six equal resistances are connected between points P, Q and R as shown in the figure. Then, the net resistance will be maximum between **(IIT-JEE 2004)**



(a) P and Q (b) Q and R

(c) P and R (d) Any two points

7. The effective resistance between points P and Q of the electrical circuit shown in the figure is **(IIT-JEE 2002)**



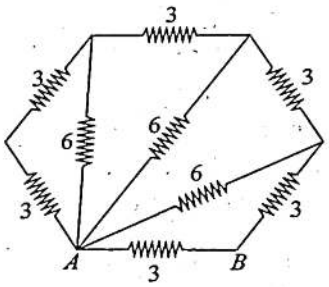
(a) $\frac{2Rr}{R+r}$ (b) $\frac{8R(R+r)}{3R+r}$

(c) $2r+4R$ (d) $\frac{5R}{2}+2r$

Numerical Types/Integer Types

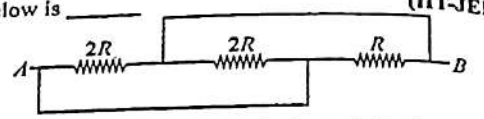
8. When two identical batteries of internal resistance 1Ω each are connected in series across a resistor R, the rate of heat produced in R is J_1. When the same batteries are connected in parallel across R, the rate is J_2. If $J_1 = 2.25J_2$ then the value of R in Ω is **(IIT-JEE 2010)**

9. All resistances in the diagram are in ohm. Find the effective resistance between the points A and B. **(IIT-JEE 1980)**

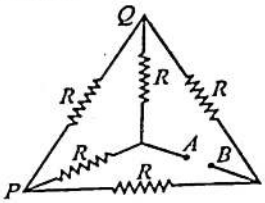


Subjective

10. The equivalent resistance between points A and B of the circuit given below is _____ **(IIT-JEE 1997)**



11. If each of the resistances in the network shown in the figure is R, what is the resistance between the terminals A and B? **(IIT-JEE 1978)**



Power and Heat Dissipated in a Circuit

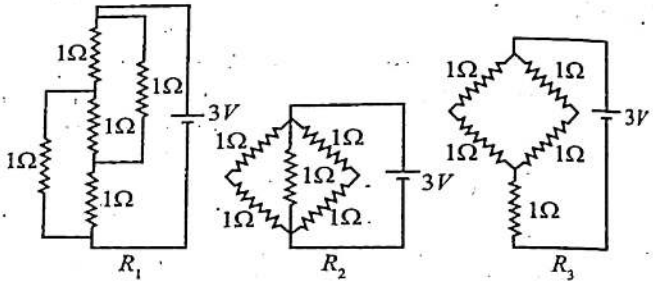
Single Correct

12. Incandescent bulbs are designed by keeping in mind that the resistance of their filament increases with the increase in temperature. If at room temperature, 100W, 60W and 40W bulbs have filament resistances R_{100} R_{60}, and R_{40}, respectively, the relation between these resistances is **(IIT-JEE 2010)**

(a) $\frac{1}{R_{100}}=\frac{1}{R_{40}}+\frac{1}{R_{60}}$ (b) $R_{100}=R_{40}+R_{60}$

(c) $R_{100}>R_{60}>R_{40}$ (d) $\frac{1}{R_{100}}>\frac{1}{R_{60}}>\frac{1}{R_{40}}$

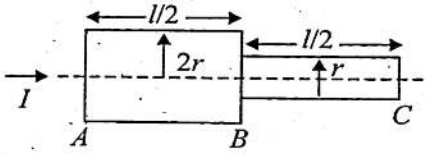
13. Figure shows three resistor configurations R_1, R_2 and R_3 connected to $3V$ battery. If the power dissipated by the configuration R_1, R_2 and R_3 is P_1, P_2 and P_3, respectively, then **(IIT-JEE 2008)**



(a) $P_1>P_2>P_3$ (b) $P_1>P_3>P_2$

(c) $P_2>P_1>P_3$ (d) $P_3>P_2>P_1$

14. Two bars of radius r and $2r$ are kept in contact as shown. An electric current I is passed through the bars. Which one of the following is correct? **(IIT-JEE 2006)**



@FAKE_CBSE X @PHYSEDUNET

(a) Heat produced in bar BC is 4 times the heat produced in bar AB

(b) Electric field in both halves is equal

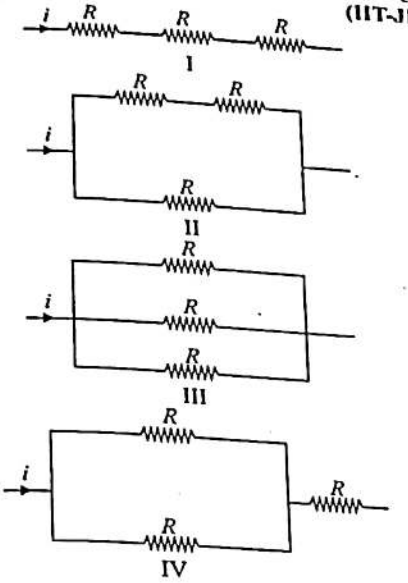
(c) Current density across AB is double that of across BC

(d) Potential difference across AB is 4 times that of across BC

15. A rigid container with thermally insulated walls contains a coil of resistance 100 Ω, carrying current 1 A. Change in internal energy after 5 min will be **(JEE Adv. 2005)**

(a) zero (b) 10 kJ (c) 20 kJ (d) 30 kJ

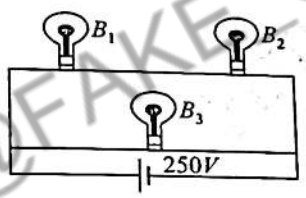
16. The three resistances of equal value are arranged in the different combinations shown below. Arrange them in increasing order of power dissipation **(IIT-JEE 2003)**



(a) III < II < IV < I (b) II < III < IV < I

(c) I < IV < III < II (d) I < III < II < IV

17. A $100W$ bulb B_1, and two $60W$ bulbs B_2 and B_3, are connected to a $250V$ source, as shown in the figure. Now W_1, W_2 and W_3 are the output powers of the bulbs B_1, B_2 and B_3 respectively. Then, **(IIT-JEE 2002)**



(a) $W_1 > W_2 = W_3$ (b) $W_1 > W_2 > W_3$

(c) $W_1 < W_2 = W_3$ (d) $W_1 < W_2 < W_3$

18. A wire of length L and 3 identical cells of negligible internal resistances are connected in series. Due to the current, the temperature of the wire is raised by ΔT in a time t. A number N of similar cells is now connected in series with a wire of the same material and cross-section but of length $2L$. The temperature of the wire is raised by the same amount ΔT in the same time. The value of N is **(IIT-JEE 2001)**

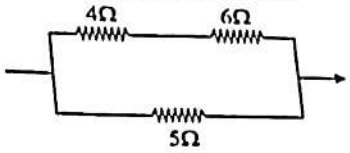
(a) 4 (b) 6 (c) 8 (d) 10

19. An electric bulb rated for $500W$ at $100V$ is used in a circuit having a $200V$ supply. The resistance R that must be put in series with the bulb, so that the bulb delivers $500W$ is _____ Ω. **(IIT-JEE 1987)**

(a) 5Ω (b) 20Ω

(c) 10Ω (d) 30Ω

20. In the circuit shown in figure the heat produced in the 5Ω resistor due to the current flowing through it is 10 cal/s.

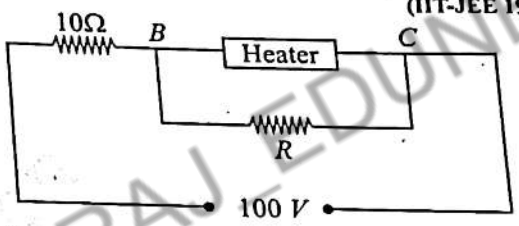


The heat generated in the 4Ω resistor is **(IIT-JEE 1981)**

(a) 1 cal/s (b) 2 cal/s

(c) 3 cal/s (d) 4 cal/s

21. A heater is designed to operate with a power of $1000W$ in a $100V$ line. It is connected in combination with a resistance of 10Ω and a resistance R, to a $100V$ mains as shown in the figure. What will be the value of R so that the heater operates with a power of $62.5W$? **(IIT-JEE 1981)**



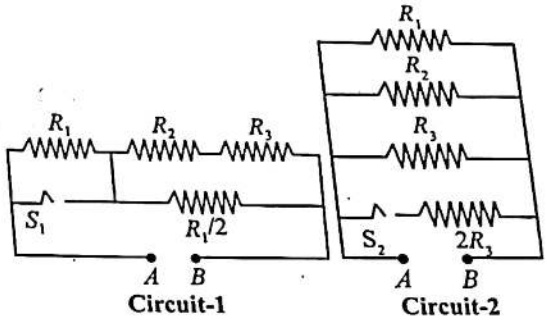
(a) 15Ω (b) 10Ω

(c) 5Ω (d) 25Ω

Multiple Correct

22. In Circuit-1 and Circuit-2 shown in the figures, $R_1 = 1\Omega$, $R_2 = 2\Omega$ and $R_3 = 3\Omega$. P_1 and P_2 are the power dissipations in Circuit-1 and Circuit-2 when the switches S_1 and S_2 are in open conditions, respectively.

Q_1 and Q_2 are the power dissipations in Circuit-1 and Circuit-2 when the switches S_1 and S_2 are in closed conditions, respectively.



Which of the following statements is/are correct?

C-14.39 W-23.42 UA-36.51 (JEE Adv. 2022)

(a) When a voltage source of 6 V is connected across A and B in both circuits, $P_1 < P_2$

(b) When a constant current source of 2 A is connected across A and B in both circuits, $P_1 > P_2$

@FAKE_CBSE_X @RAJ_EDUNET

(c) When a voltage source of 6 V is connected across A and B in Circuit-1, $Q_1 > P_1$

(d) When a constant current source of 2 A is connected across A and B in both circuits, $Q_2 < Q_1$

23. An incandescent bulb has a thin filament of tungsten that is heated to high temperature by passing an electric current. The hot filament emits black-body radiation. The filament is observed to break up at random locations after a sufficiently long time of operation due to non-uniform evaporation of tungsten from the filament. If the bulb is powered at constant voltage, which of the following statement(s) is/ are true?

C-3.16 W-30.4 UA-55.22 PC-11.23 (JEE Adv. 2016)

(a) The temperature distribution over the filament is uniform.

(b) The resistance over small sections of the filament decreases with time.

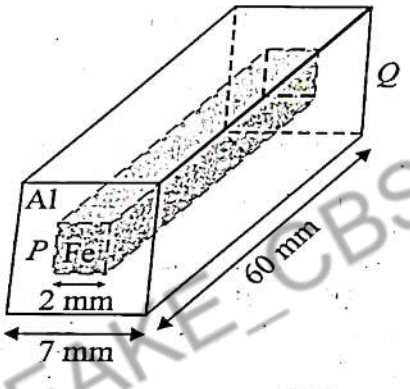
(c) The filament emits more light at higher band of frequencies before it breaks up.

(d) The filament consumes less electrical power towards the end of the life of the bulb.

Problem Solving Using Ohm's Law

Single Correct

24. In an aluminium (Al) bar of square cross section, a square hole is drilled and is filled with iron (Fe) as shown in the figure. The electrical resistivities of Al and Fe are $27 \times 10^{-8}\ \Omega$m and $10 \times 10^{-7}\ \Omega$m, respectively. The electrical resistance between the two faces P and Q of the composite bar is **(JEE Adv. 2015)**

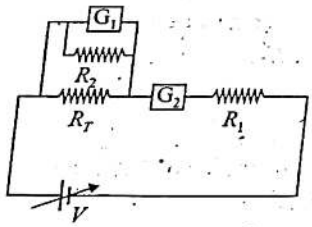


(a) $\frac{2475}{64}\mu\Omega$ (b) $\frac{1875}{64}\mu\Omega$

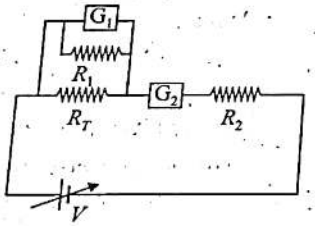
(c) $\frac{1875}{49}\mu\Omega$ (d) $\frac{2475}{132}\mu\Omega$

25. To verify Ohm's law, a student is provided with a test resistor, a high resistance, a small resistance, two identical galvanometers and a variable voltage source. The correct circuit to carry out the experiment is **(IIT-JEE 2010)**

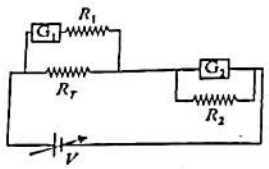
(a)



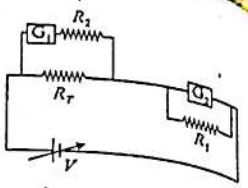
(b)



(c)

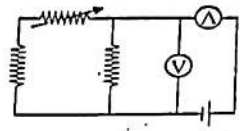


(d)



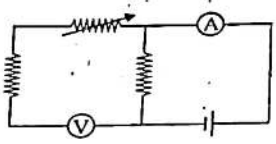
26. Which of the following set-up can be used to verify ohm's law? **(IIT-JEE 2003)**

(a)

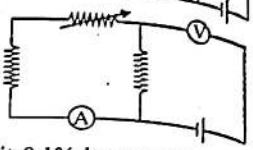


(b)

(c)



(d)



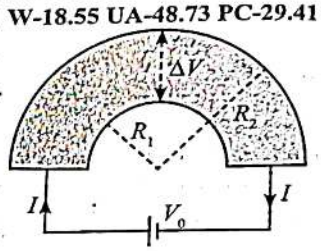
27. A copper wire is stretched to make it 0.1% longer. What is the percentage change in its resistance? **(IIT-JEE 1997)**

(a) 0.2% (b) 0.5% (c) 0.1% (d) 0.05%

Multiple Correct

28. Shown in the figure is a semicircular metallic strip that has thickness t and resistivity ρ. Its inner radius is R_1 and outer radius is R_2. If a voltage V_0 is applied between its two ends, a current I flows in it. In addition, it is observed that a transverse voltage ΔV develops between its inner and outer surfaces due to purely kinetic effects of moving electrons (ignore any role of the magnetic field due to the current). Then (figure is schematic and not drawn to scale)

C-3.31 W-18.55 UA-48.73 PC-29.41 (JEE Adv. 2020)



(a) $I = \frac{V_0 t}{\pi\rho}\ln\left(\frac{R_2}{R_1}\right)$

(b) the outer surface is at a higher voltage than the inner surface

(c) the outer surface is at a lower voltage than the inner surface

(d) $\Delta V \propto I^2$

29. Read the following statements:

Y : The resistivity of semiconductor decreases with increase of temperature.

Z : In a conducting solid, the rate of collisions between free electrons and ions increases with increase of temperature.

Select the correct statement(s) from the following: **(IIT-JEE 1993)**

(a) Y is true but Z is false

(b) Y is false but Z is true

(c) Both Y and Z are true

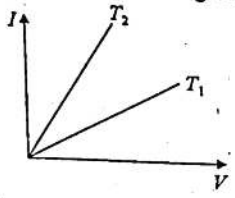
(d) Y is true and Z is the correct reason for Y

@FAKE_CBSE X @FAKE_EDUNET

30. When a potential difference is applied across, the current passing through (IIT-JEE 1999)
(a) an insulator at 0 K is zero
(b) a semiconductor at 0 K is zero
(c) a metal at 0 K is finite
(d) a p-n diode at 300 K is finite, if it is reverse biased

True/False

31. The current-voltage graphs for a given metallic wire at two different temperatures T_1 and T_2 are shown in the figure.



The temperature T_2 is greater than T_1. (IIT-JEE 1985)

Subjective

32. Draw the circuit for experimental verification of Ohm's law using a source of variable DC voltage, a main resistance of 100 Ω, two galvanometers and two resistances of values 10^6 Ω and 10^{-3} Ω respectively. Clearly show the positions of the voltmeter and the ammeter. (IIT-JEE 2004)

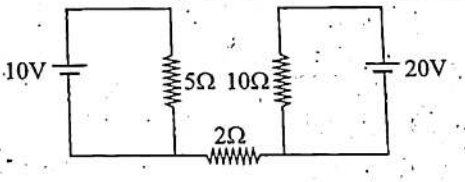
33. A 25 W and a 100 W bulb are joined in series and connected to the mains. Which bulb will glow brighter? (IIT-JEE 1979)

34. A copper wire having cross-sectional area of 0.5 mm² and a length of 0.1 m is initially at 25°C and is thermally insulated from the surrounding. If a current of 1.0 A is set up in this wire,
(a) find the time in which the wire will start melting. The change of resistance with the temperature of the wire may be neglected.
(b) What will this time be, if the length of the wire is doubled?
Melting point of copper = 1075°C, Specific resistance of copper = 1.6×10^{-8} Ωm, Density of copper = 9×10^3 kg/m³, Specific heat of copper = 9×10^{-2} cal/kg°C (IIT-JEE 1979)

Kirchhoff's Law and Equivalent Battery

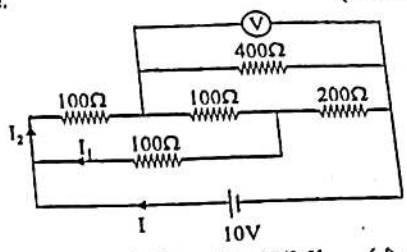
Single Correct

35. Find out the value of current through 2Ω resistance for the given circuit. (IIT-JEE 2005)



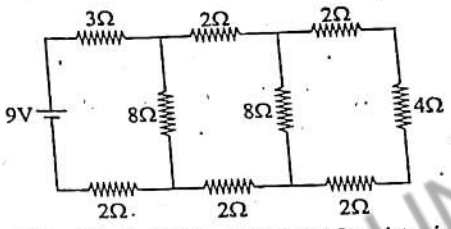
(a) 5A (b) 2A (c) Zero (d) 4A

36. An electrical circuit is shown in figure. Calculate the potential difference across the resistor of 400Ω as will be measured by the voltmeter V of resistance 400Ω either by applying Kirchhoff's rules or otherwise. (IIT-JEE 1996)



(a) 20/7 V (b) 50/3 V (c) 10/3 V (d) 20/3 V

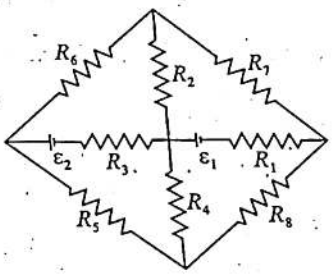
37. In the circuit shown in the figure, the current through (IIT-JEE 1995)



(a) The 3Ω resistor is 0.50A (b) The 3Ω resistor is 0.25A
(c) The 4Ω resistor is 0.50A (d) The 4Ω resistor is 0.25A

Multiple Correct

38. The figure shows a circuit having eight resistances of 1Ω each, labelled R_1 to R_8, and two ideal batteries with voltages $\varepsilon_1 = 12$ V and $\varepsilon_2 = 6$ V. C-05.55 W-0.00 UA-64.56 (JEE Adv. 2022)



Which of the following statements is/are correct?
(a) The magnitude of current flowing through R_1 is 7.2 A
(b) The magnitude of current flowing through R_2 is 1.2 A
(c) The magnitude of current flowing through R_3 is 4.8 A
(d) The magnitude of current flowing through R_5 is 2.4 A

39. Two identical moving coil galvanometer have 10 Ω resistance and full scale deflection at 2 μA current. One of them is converted into a voltmeter of 100 mV full scale reading and the other into an Ammeter of 1 mA full scale current using appropriate resistors. These are then used to measure the voltage and current in the Ohm's law experiment with R = 1000 Ω resistor by using an ideal cell. Which of the following statements is/are correct? C-7 W-28 UA-44 PC-20 (JEE Adv. 2019)

@TAKE_OBSE_X @RAU_EDUNET

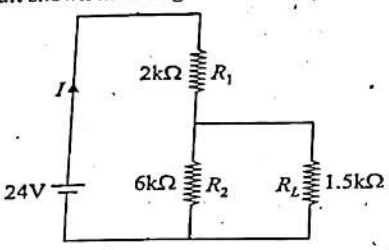
(a) The measured value of R will be $978\ \Omega < R < 982\ \Omega$

(b) The resistance of the Voltmeter will be $100\ k\Omega$

(c) The resistance of the Ammeter will be $0.02\ \Omega$ (round off to 2nd decimal place)

(d) If the ideal cell is replaced by a cell having internal resistance of 5Ω then the measured value of R will be more than 1000Ω

40. For the circuit shown in the figure **(IIT-JEE 2009, 2015)**



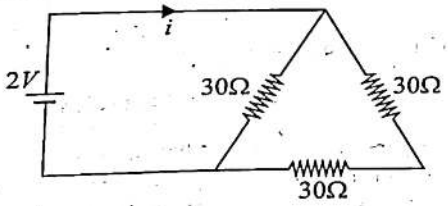
(a) The current I through the battery is $7.5mA$

(b) The potential difference across R_L is $18V$

(c) Ratio of powers dissipated in R_1 and R_2 is 3

(d) If R_1 and R_2 are interchanged, magnitude of the power dissipated in R_L will decrease by a factor of 9

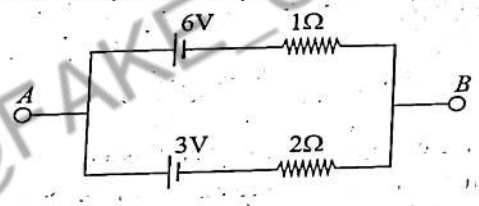
41. The current i in the circuit (see figure) is **(IIT-JEE 1983)**



(a) $1/45A$ (b) $1/15A$ (c) $1/10A$ (d) $1/5A$

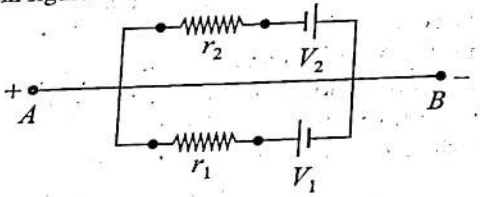
Numerical Types/Integer Types

42. Two batteries of different emfs and different internal resistances are connected as shown. The voltage across AB in volt is **(IIT-JEE 2011)**

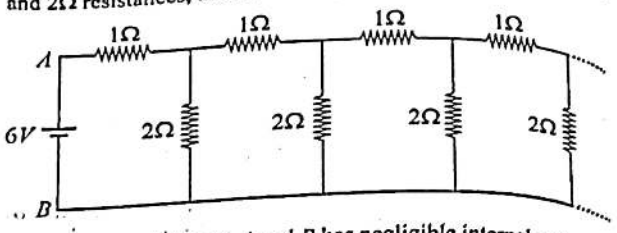


Subjective

43. Find the emf (V) and internal resistance (r) of a single battery which is equivalent to a parallel combination of two batteries of emfs V_1 and V_2 and internal resistances r_1 and r_2 respectively, with polarities as shown in figure. **(IIT-JEE 1997)**



44. An infinite ladder network of resistances is constructed with 1Ω and 2Ω resistances, as shown in figure.

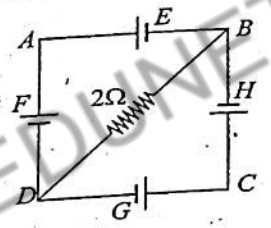


The $6V$ battery between A and B has negligible internal resistance. **(IIT-JEE 1987)**

(i) Show that the effective resistance between A and B is 2Ω.

(ii) What is the current that passes through the 2Ω resistance nearest to the battery?

45. In the circuit shown in figure E, F, G, H are cells of emf 2, 1, 3 and $1V$ respectively, and their internal resistances are 2, 1, 3 and 1Ω respectively.



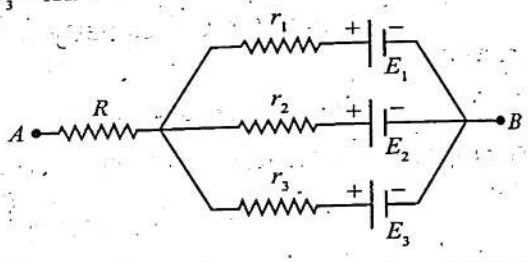
Calculate

(i) the potential difference between B and D and

(ii) the potential difference across the terminals of each cells G and H. **(IIT-JEE 1984)**

46. Two resistors, 400Ω and 800Ω are connected in series with a $6\ V$ battery. It is desired to measure the current in the circuit. An ammeter of 10Ω resistance is used for this purpose. What will be the reading in the ammeter? Similarly, if a voltmeter of 1000Ω resistance is used to measure the potential difference across the 400Ω resistor, what will be the reading in the voltmeter? **(IIT-JEE 1982)**

47. In the circuit shown in figure $E_1 = 3V$, $E_2 = 2V$, $E_3 = 1V$ and $R = r_1 = r_2 = r_3 = 1\Omega$. **(IIT-JEE 1981)**



(a) Find the potential difference between the points A and B and the currents through each branch.

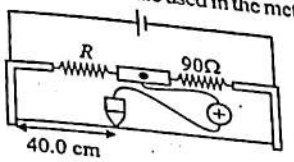
(b) If r_2 is short-circuited and the point A is connected to point B, find the currents through E_1, E_2, E_3 and the resistor R.

@FAKE_CBSE_X @RAJ_EDUNET

Current Measuring Instrument, Problem Based on Wheatstone Bridge

Single Correct

48. During an experiment with a meter bridge, the galvanometer shows a null point when the jockey is pressed at 40.0 cm using a standard resistance of 90Ω, as show in the scale used in the meter bridge is 1 mm.



The unknown resistance is

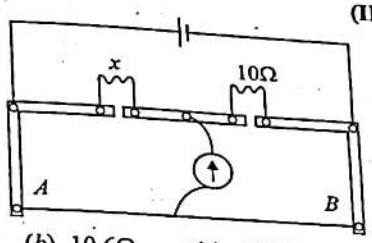
C-37.7 W-43.02 UA-19.28 (JEE Adv. 2014)

(a) $60 \pm 0.15\Omega$ (b) $135 \pm 0.56\Omega$

(c) $60 \pm 0.25\Omega$ (d) $135 \pm 0.23\Omega$

49. A meter bridge is set-up as shown in figure, to determine an unknown resistance X using a standard 10Ω resistor. The galvanometer shows null point when tapping-key is at 52 cm mark. The end-corrections are 1 cm and 2 cm respectively for the ends A and B. The determined value of X is

(IIT-JEE 2011)



(a) 10.2Ω (b) 10.6Ω (c) 10.8Ω (d) 11.1Ω

50. **Statement-I:** In a meter bridge experiment, null point for an unknown resistance is measured. Now, the unknown resistance is put inside an enclosure maintained at a higher temperature. The null point can be obtained at the same point as before by decreasing the value of the standard resistance.

Statement-II: Resistance of a metal increases with increase in temperature.

(IIT-JEE 2008)

(a) If Statement-I is true, Statement-II is true; Statement-II is the correct explanation for Statement-I

(b) If Statement-I is true, Statement-II is true; Statement-II is not a correct

(c) If Statement-I is true; Statement-II is false

(d) If Statement-I is false; Statement-II is true

51. A resistance of 2Ω is connected across one gap of a meter-bridge (the length of the wire is 100 cm) and an unknown resistance, greater than 2Ω, is connected across the other gap. When these resistances are interchanged, the balance point shifts by 20 cm. Neglecting any corrections, the unknown resistance is (IIT-JEE 2007)

(a) 3Ω (b) 4Ω (c) 5Ω (d) 6Ω

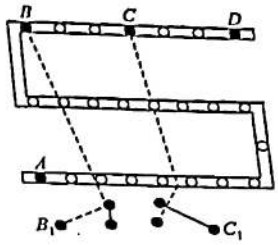
52. A moving coil galvanometer of resistance 100Ω is used as an ammeter using a resistance 0.1Ω. The maximum deflection current in the galvanometer is 100μA. Find the current in the circuit, so that the ammeter shows maximum deflection. (IIT-JEE 2005)

(a) 100.1mA (b) 1000.1mA

(c) 10.01mA (d) 1.01mA

53. For the post office box arrangement to determine the value of unknown resistance, the unknown resistance should be connected between

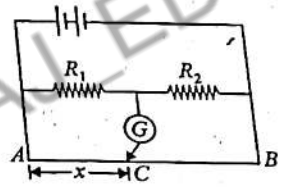
(IIT-JEE 2004)



(a) B and C (b) C and D (c) A and D (d) B_1 and C_1

54. In the shown arrangement of the experiment of the meter bridge if AC corresponding to null deflection of galvanometer is x, what would be its value if the radius of the wire AB is doubled?

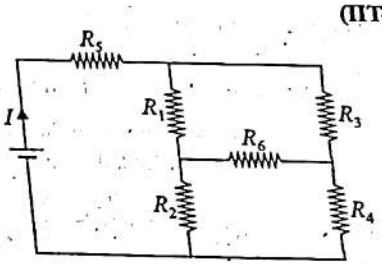
(IIT-JEE 2003)



(a) x (b) $x/4$ (c) $4x$ (d) $2x$

55. In the given circuit, it is observed that the current I is independent of the value of the resistance R_6. Then, the resistance values must satisfy

(IIT-JEE 2001)



(a) $R_1R_2R_5 = R_3R_4R_6$

(b) $\frac{1}{R_5}+\frac{1}{R_6}=\frac{1}{R_1+R_2}+\frac{1}{R_3+R_4}$

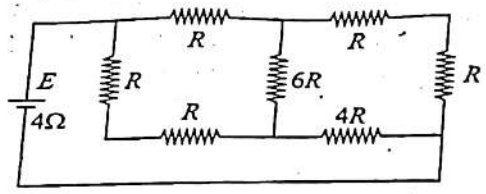
(c) $R_1R_4 = R_2R_3$

(d) $R_1R_3 = R_2R_4$

56. A battery of internal resistance 4Ω is connected to the network of resistances as shown in figure. In order that the maximum power can be delivered to the network, the value of R in Ω should be

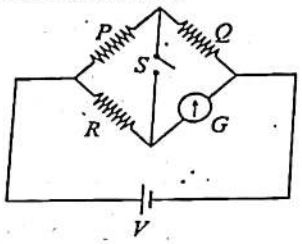
(IIT-JEE 1995)

@FAKE_CORSE X @RAJEDUNET



(a) 4/9 (b) 2 (c) 8/3 (d) 18

57. In the circuit shown $P \neq R$, the reading of galvanometer is same with switch S open or closed. Then **(IIT-JEE 1999)**



(a) $I_R = I_G$ (b) $I_P = I_G$ (c) $I_Q = I_G$ (d) $I_Q = I_R$

Multiple Correct

58. Consider two identical galvanometers and two identical resistors with resistance R. If the internal resistance of the galvanometers $R_c < R/2$, which of the following statement(s) about any one of the galvanometers is/are true?

C-5.46 W-43.69 UA-40.95 PC-9.9 (JEE Adv. 2016)

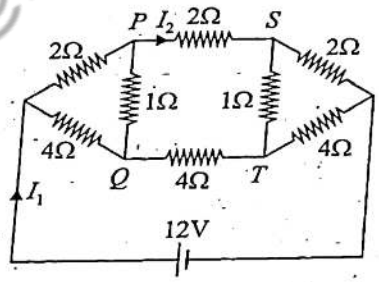
(a) The maximum voltage range is obtained when all the components are connected in series

(b) The maximum voltage range is obtained when the two resistors and one galvanometer are connected in series, and the second galvanometer is connected in parallel to the first galvanometer

(c) The maximum current range is obtained when all the components are connected in parallel

(d) The maximum current range is obtained when the two galvanometers are connected in series, and the combination is connected in parallel with both the resistors

59. For the resistance network shown in the figure, choose the correct option(s). **C-13.08 W-79.33 UA-7.6 (IIT-JEE 2012)**



(a) The current through PQ is zero

(b) $I_1 = 3A$

(c) The potential at S is less than that at Q

(d) $I_2 = 2A$

60. A micro-ammeter has a resistance of 100Ω and full scale range of 50μA. It can be used as a voltmeter or as a higher range ammeter provided a resistance is added to it. Pick the correct range and resistance combination (s) **(IIT-JEE 1991)**

(a) 50 V range with 10 kΩ resistance in series

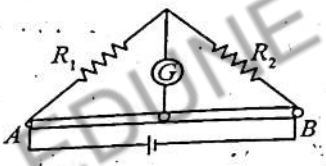
(b) 10 V range with 200 kΩ resistance in series

(c) 5 mA range with 1Ω resistance in parallel

(d) 10 mA range with 1Ω resistance in parallel

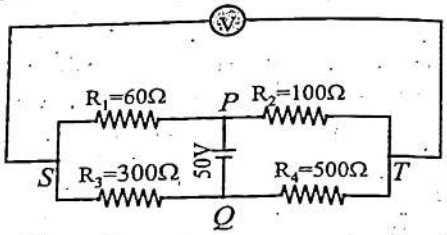
Numerical Types/Integer Types

61. Two resistances $R_1 = X\Omega$ and $R_2 = 1\Omega$ are connected to a wire AB of uniform resistivity, as shown in the figure. The radius of the wire varies linearly along its axis from 0.2 mm at A to 1 mm at B. A galvanometer (G) connected to the center of the wire, 50 cm from each end along its axis, shows zero deflection when A and B are connected to a battery. The value of x is **C-9.83 W-22.8 UA-67.37 (JEE Adv. 2022)**



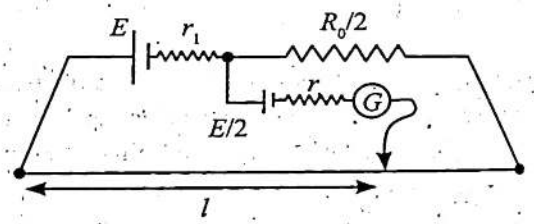
62. In the balanced condition, the values of the resistances of the four arms of a Wheatstone bridge are shown in the figure below. The resistance R_3 has temperature coefficient 0.0004 °C^{-1}. If the temperature of R_3 is increased by 100 °C, the voltage developed between S and T will be _____ volt.

C-3.01 W-72.29 UA-24.7 (JEE Adv. 2020)



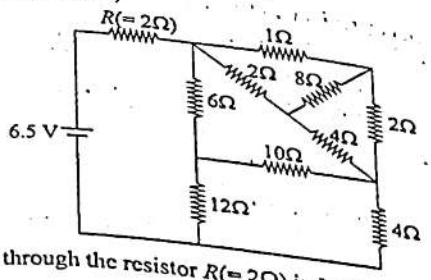
63. In order to measure the internal resistance r_1 of a cell of emf E, a meter bridge of wire resistance $R_0 = 50\ \Omega$, a resistance $R_0/2$, another cell of emf $E/2$ (internal resistance r) and a galvanometer G are used in a circuit, as shown in the figure. If the null point is found at $l = 72$ cm, then the value of $r_1 = \ldots\Omega$.

C-9.7 W-70.34 UA-19.95 (JEE Adv. 2021)



@FAKE_CBSE_X@RAJ_EDUNET

64. In the following circuit,



the current through the resistor $R(=2\Omega)$ is I amperes. The value of I is _____.

(JEE Adv. 2015)

65. A galvanometer gives full scale deflection with 0.006 A current. By connecting it to a 4990 Ω resistance, it can be converted into a voltmeter of range 0-30 V. If connected to a $\frac{2n}{249}\Omega$ resistance, becomes an ammeter of range 0-1.5 A. The value of n is _____.

(JEE Adv. 2014)

Subjective

66. Show by diagram, how can we use a rheostat as the potential divider?

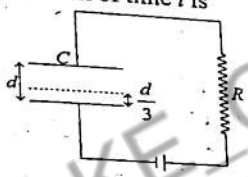
(IIT-JEE 2003)

RC Circuit

Single Correct

67. A parallel plate capacitor C with plates of unit area and separation d is filled with a liquid of dielectric constant $K=2$. The level of liquid is $d/3$ initially. Suppose the liquid level decreases at a constant speed v, the time constant as a function of time t is

(IIT-JEE 2008)

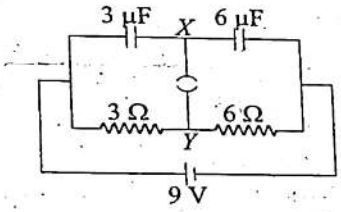


(a) $\frac{6\varepsilon_0 R}{5d+3vt}$ (b) $\frac{(15d+9vt)\varepsilon_0 R}{2d^2-3dvt-9v^2t^2}$

(c) $\frac{6\varepsilon_0 R}{5d-3vt}$ (d) $\frac{(15d-9vt)\varepsilon_0 R}{2d^2+3dvt-9v^2t^2}$

68. A circuit is connected as shown in the figure with the switch S open. When the switch is closed, the total amount of charge that flows from Y to X is

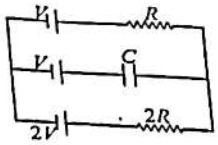
(IIT-JEE 2007)



(a) zero (b) 54 μC (c) 27 μC (d) 81 μC

69. In the given circuit, with steady current, the potential difference across the capacitor must be

(IIT-JEE 2001)

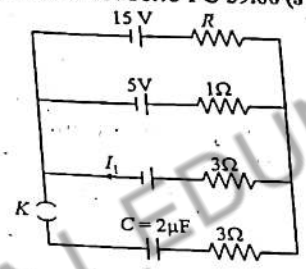


(a) V (b) $V/2$ (c) $V/3$ (d) $2V/3$

Multiple Correct

70. In a circuit shown in the figure, the capacitor C is initially uncharged and the key K is open. In this condition, a current of $1A$ flows through the 1Ω resistor. The key is closed at time $t=t_0$. Which of the following statements is/are correct? [Given: $e^{-1}=0.36$]

C-1.62 W-0 UA-58.73 PC-39.66 (JEE Adv. 2023)



(a) The value of the resistance R is 3Ω.

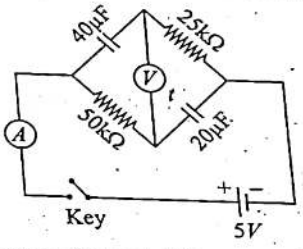
(b) For $t<t_0$, the value of current I_1 is $2A$.

(c) At $t=t_0+7.2$ μs, the current in the capacitor is $0.6A$.

(d) For $t\to\infty$, the charge on the capacitor is 12 μC.

71. In the circuit shown below, the key is pressed at time $t=0$. Which of the following statement(s) is/are true?

C-1.82 W-0 UA-47.97 PC-50.21 (JEE Adv. 2016)



(a) The voltmeter displays $-5V$ as soon as the key is pressed, and displays $+5V$ after a long time

(b) The voltmeter will display $0V$ at time $t=\ln 2$ second

(c) The current in the ammeter becomes $1/e$ of the initial value after 1 second

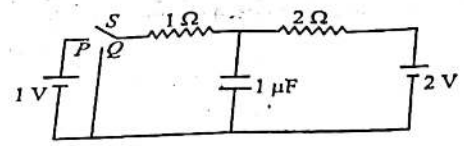
(d) The current in the ammeter becomes zero after a long time

Comprehension-Based/Passage Based

Comprehension (Q.72 to 73) In the circuit shown below, the switch S is connected to position P for a long time so that the charge on the capacitor becomes q_1 μC. Then S is switched to position Q. After a long time, the charge on the capacitor is q_2 μC.

(JEE Adv. 2021)

@FAKE_CBSE_X_@RAJ_EDUNET



72. The magnitude of q_1 is _____. **C-18.77 W-64.89 UA-16.34**

73. The magnitude of q_2 is _____. **C-18.54 W-62.7 UA-18.77**

Passage

Consider a simple RC circuit as shown in Figure 1.

Process 1 In the circuit, the switch S is closed at $t = 0$ and the capacitor is fully charged to voltage V_0 (i.e. charging continues for time $T >> RC$). In the process, some dissipation (E_D) occurs across the resistance R. The amount of energy finally stored in the fully charged capacitor is E_C.

Process 2 In a different process the voltage is first set to $\frac{V_0}{3}$ and maintained for a charging time $T >> RC$. Then, the voltage is raised to $\frac{2V_0}{3}$ without discharging the capacitor and again maintained for a time $T >> RC$. The process is repeated one more time by raising the voltage to V_0 and the capacitor is charged to the same final voltage V_0 as in process 1.

These two processes are depicted in Figure 2.

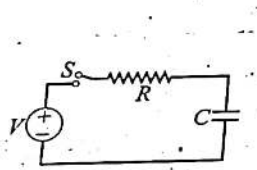


Figure 1

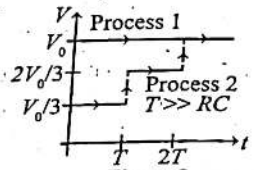


Figure 2

74. In process 1, the energy stored in the capacitor E_C and heat dissipated across resistance E_D are related by

(a) $E_C = E_D \ln 2$ (b) $E_C = E_D$

(c) $E_C = 2E_D$ (d) $E_C = \frac{1}{2}E_D$

75. In process 2, total energy dissipated across the resistance E_D is **(JEE Adv. 2015)**

(a) $E_D = \frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$

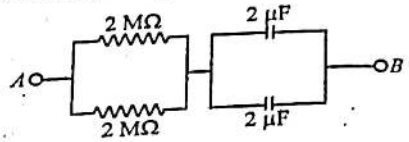
(b) $E_D = 3\left(\frac{1}{2}CV_0^2\right)$

(c) $E_D = 3CV_0^2$

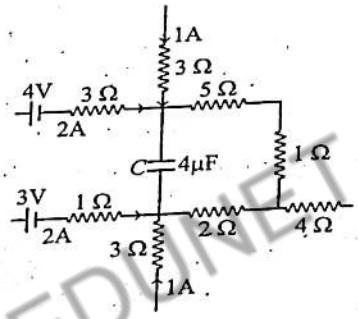
(d) $E_D = \frac{1}{2}CV_0^2$

Numerical Types/Integer Types

76. At time $t = 0$, a battery of 10 V is connected across points A and B in the given circuit. If the capacitors have no charge initially, at what time (in second) does the voltage across them become 4 V? [Take : ln 5 = 1.6, ln 3 = 1.1] **(IIT-JEE 2010)**

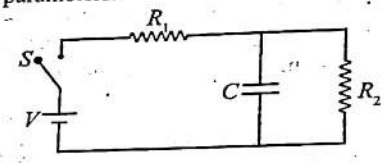


77. A part of circuit in a steady state along with the currents flowing in the branches, the values of resistances etc, is shown in the figure. Calculate the energy stored in the capacitor C (4μF). **(IIT-JEE 1986)**

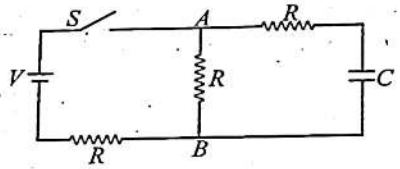


Subjective

78. At $t = 0$, switch S is closed. The charge on the capacitor is varying with time as $Q = Q_0(1 - e^{-\alpha t})$. Obtain the value of Q_0 and α in the given circuit parameters. **(IIT-JEE 2005)**



79. In the circuit shown in figure, the battery is an ideal one, with emf V. The capacitor is initially uncharged. The switch S is closed at time $t = 0$. **(IIT-JEE 1998)**



(a) Find the charge Q on the capacitor at time t.

(b) Find the current in AB at time t. What is its limiting value as $t \to \infty$?

@FAKE_CBSE X@RAI EDUNET

ANSWER KEY

JEE-Main

1. (b)	2. (c)	3. (b)	4. [22]	5. (b)	6. (32)	7. (16)	8. [748]	9. (1027)	10. [300]
11. (c)	12. [48]	13. [12]	14. (a)	15. [144]	16. (a)	17. (a)	18. (b)	19. (d)	20. [5]
21. (d)	22. (c)	23. (c)	24. (a)	25. (b)	26. (c)	27. (a,c,d)	28. (a)	29. (d)	30. (d)
31. (b)	32. (d)	33. (a)	34. (a)	35. [30]	36. [1]	37. [5]	38. (b)	39. (d)	40. (d)
41. (b)	42. (a)	43. (a)	44. (a)	45. (b)	46. (b)	47. (d)	48. (d)	49. (d)	50. [10]
51. [2]	52. [100]	53. (b)	54. [4]	55. (b)	56. (a)	57. (a)	58. (a)	59. [8]	60. [2]
61. [3]	62. (c)	63. (b)	64. (b)	65. (a)	66. (d)	67. (b)	68. [9]	69. [6]	70. [3]
71. [3]	72. [70]	73. [2]	74. [20]	75. [4]	76. [4]	77. [10]	78. (c)	79. (b)	80. [10]
81. (b)	82. (a)	83. (c)	84. (a)	85. (b)	86. (d)	87. (c)	88. [3]	89. (1)	90. (b)
91. (c)	92. [5]	93. (b)	94. (d)	95. (a)	96. (a)	97. [16]	98. [14]	99. [450]	100. (a, b, c)
101. (a)	102. (a)	103. (d)	104. (a)	105. [3840]	106. [4]	107. [2500]	108. [50]	109. (b)	110. (c)
111. (a)	112. (a)	113. (a)	114. (d)	115. (a)	116. (b)	117. (b)	118. (a)	119. [6]	120. (1)
121. (a)	122. [25]	123. (a)	124. (c)	125. (a)	126. (a)	127. (d)	128. (d)	129. [4]	130. [2]
131. [10]	132. (a, b, c, d)		133. (c)	134. (a)	135. (a)	136. [30]	138. (c)	139. (d)	140. (d)
141. (c)	142. (c)	143. (200)	144. (c)	145. (c)	146. (d)	148. (c)	149. (a)	150. (d)	151. (c)
152. (2500)	153. (160)	154. (b)	155. (c)	156. (a)	157. (c)	158. [30]	159. [20]	160. [50]	161. [2]
162. [5]	163. (b)	164. (b)	165. (b)	166. (d)	167. [2400]	168. [19]	169. [40]	170. [10]	171. [8]
172. [20]	173. [5]	174. (a)	175. (d)	176. (c)	177. [48]	178. [3]	179. (a)	180. (c)	181. (d)
182. (a)	183. [40]	184. [2]	185. (a)	186. (b)	187. (c)	188. (a)	189. (c)	190. (c)	191. (*)
192. (b)	193. (c)	194. (c)	195. (b)	196. (d)	197. (c)	198. (b)	199. (d)	200. (b)	201. (a,c)
202. [400]	203. [81]	204. [36]	205. (d)	206. [60]	207. [4]	208. [75]	209. (a)	210. (b)	211. (a,b,c,d)
212. (d)	213. [10]	214. (b)	215. [100]	216. (d)	217. (d)	218. [2]	221. (a)	222. [8]	223. [6]
224. (a)	225. (c,d)								

JEE-Advanced

1. (c)	2. (c)	3. (d)	4. (d)	5. [False]	6. (a)	7. (a)	8. [4]	9. [2]	12. (d)
13. (c)	14. (a)	15. (d)	16. (a)	17. (d)	18. (b)	19. (b)	20. (b)	21. (c)	22. (a, b, c)
23. (c, d)	24. (b)	25. (c)	26. (a)	27. (a)	28. (a,c,d)	29. (c)	30. (a,b,d)	31. [False]	35. (c)
36. (d)	37. (d)	38. (a,b,c,d)	39. (a, c)	40. (a,d)	41. (c)	42. [5]	48. (c)	49. (b)	50. (d)
51. (a)	52. (a)	53. (c)	54. (a)	55. (c)	56. (b)	57. (a)	58. (a, c)	59. (a,b,c,d)	60. (b,c)
61. [5]	62. [0.26 to 0.28]	63.	[3] 64.	[1] 65.	[5] 67.	(a) 68.	(c) 69.	(c)	
70. (a, b, c, d)	71. (a,b,c,d)	72. [1.33]	73. [0.67]	74. (b)	75. (a)	76. [2]	77. [0.288]		

@FAKE_CBSE_X@RAJ_EDUNET

EXPLANATIONS

JEE-Main

1. (*b*) Given that
Current $I = I_0 + \beta t$
$I_0 = 20\ A$
$b = 3A/s$
$I = 20 + 3t$

$$\frac{dq}{dt} = 20 + 3t$$

$$\int_0^q dp = \int_0^{20} (20 + 3t)dt$$

$$q = \int_0^{20} 20dt + \int_0^{20} 3t\,dt$$

$$q = \left[20t + \frac{3t^2}{2}\right]_0^{20} = 1000C$$

2. (*c*) Given, $R_{T=27} = 60\ \Omega$
$V = 220\ V$
$I_T = 2.75\ A$
Hence,

$$R_T = \frac{220}{2.75} = 80\ \Omega$$

Now,
We know that,
$R = R_0\,(1 + \alpha\Delta T)$
Hence,
$80 = 60\,[1 + 2 \times 10^{-4}\,(T - 27)$
$T \approx 1694°C$

3. (*b*)For series combination,
$R_{eq} = R_1 + R_2$

$$2R\left(1 + \alpha_{eq}\Delta\theta\right) = R\left(1 + \alpha_1\Delta\theta\right) + R\left(1 + \alpha_2\Delta\theta\right)$$

$$2R\left(1 + \alpha_{eq}\Delta\theta\right) = 2R + \left(\alpha_1 + \alpha_2\right)R\Delta\theta$$

$$\alpha_{eq} = \frac{\alpha_1 + \alpha_2}{2}$$

For parallel combination,

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{\frac{R}{2}\left(1 + \alpha_{eq}\Delta\theta\right)} = \frac{1}{R\left(1 + \alpha_1\Delta\theta\right)} + \frac{1}{R\left(1 + \alpha_2\Delta\theta\right)}$$

$$\frac{2}{1 + \alpha_{eq}\Delta\theta} = \frac{1}{1 + \alpha_1\Delta\theta} + \frac{1}{1 + \alpha_2\Delta\theta}$$

$$\frac{2}{1 + \alpha_{eq}\Delta\theta} = \frac{1 + \alpha_2\Delta0 + 1 + \alpha_1\Delta0}{(1 + \alpha_1\Delta0)(1 + \alpha_2\Delta0)}$$

$$2\left[(1 + \alpha_1\Delta\theta)(1 + \alpha_2\Delta\theta)\right]$$

$$= \left[2 + (\alpha_1 + \alpha_2)\Delta\theta\right]\left[1 + \alpha_{eq}\Delta\theta\right]$$

$$2\left[1 + \alpha_1\Delta\theta + \alpha_2\Delta\theta + \alpha_1\alpha_2\Delta\theta\right]$$

$$= 2 + 2\alpha_{eq}\Delta\theta + (\alpha_1 + \alpha_2)\Delta\theta + \alpha_{eq}(\alpha_1 + \alpha_2)\Delta\theta^2$$

Neglecting small terms

$$2 + 2(\alpha_1 + \alpha_2)\Delta\theta$$

$$= 2 + 2\alpha_{eq}\Delta\theta + (\alpha_1 + \alpha_2)\Delta\theta$$

$$(\alpha_1 + \alpha_2)\Delta\theta = 2\alpha_{eq}\Delta\theta$$

$$\alpha_{eq} = \frac{\alpha_1 + \alpha_2}{2}$$

4. [22] $q = \int_1^2 i\,dt$

$$\Rightarrow q = \left(t^3 + t^4\right)\Big|_1^2 \quad [I = 3t^2 + 4t^3]$$

$\therefore q = 22C$

5. (*b*) Given $R_{100} = 10\Omega$, $R_0 = 8\Omega$

$$\therefore R_{100} = R_0\left(1 + \alpha\Delta T\right)$$

$$\Rightarrow 10 = 8\left(1 + \alpha \times 100\right) \Rightarrow 100\alpha = \frac{1}{4}$$

Also, $R_{100} = R_0\left(1 + \alpha\Delta T\right)$

$$\Rightarrow R_{400} = 8\left(1 + 400\alpha\right) = 8\left(1 + 1\right) = 16\Omega$$

6. (32)

$$\because R = \frac{\rho\ell}{A} = \frac{\rho V}{A^2} \Rightarrow R \propto \frac{1}{r^4}$$

$$\therefore \frac{R_A}{R_B} = \frac{r_B^4}{r_A^4}$$

$$\Rightarrow \frac{R_A}{2} = \left[\frac{4 \times 10^{-3}}{2 \times 10^{-3}}\right]^4 \Rightarrow R_A = 32\Omega$$

7. (16)

From $R = \frac{\rho l}{A}, R \propto \frac{l}{r^2}$

On starching the wire, the length increases, but radius decreases to keep the volume constant, therefore
initial volume = final volume

$$\pi r^2 l = \pi\frac{r^2}{4}l'$$

$$l' = 4l$$

$$\frac{R_1}{R_2} = \left(\frac{4l}{\frac{r^2}{4}}\right)\frac{r^2}{l} = 16$$

$$R_1 = 16\,R \Rightarrow x = 16$$

8. [748]
Resistance of the wire,

$$R = R_0(1 + \alpha\Delta T)$$

$$\frac{\Delta R}{R_0} = \alpha\Delta T$$

Case-I $0°C \rightarrow 100°C$

$$\frac{10.2 - 10}{10} = \alpha(100 - 0) \quad ...(i)$$

Case-II $0°C \rightarrow t°C$

$$\frac{10.95 - 10}{10} = \alpha(t - 0) \quad ...(ii)$$

$t = 475 + 273 = 748\ K$

9. (1027) We have given the resistance of the element in 50Ω and
$\alpha = 2.4 \times 10^{-4}°C^{-1}$
$R = R0(1 + \alpha\Delta T)$
$62 = 50\,[1 + 2.4 \times 10^{-4}\Delta T]$
$\Delta T = 1000°C \Rightarrow T - 27° = 1000°C$
$T = 1027°C$

10. [300] Volume of wire will remain constant

$$\Rightarrow \pi r_1^2\ell_1 = \pi r_2^2\left(2\ell_1\right)$$

$$r_2 = \frac{r_1}{\sqrt{2}}$$

$$R_2 = \frac{\rho\ell_2}{\pi r_2^2} = \frac{\rho 2\ell_1}{\pi\left(\frac{r_1}{\sqrt{2}}\right)^2}$$

$$R_2 = 4\frac{\rho\,\ell_1}{\pi r_1^2}$$

$$R_2 = 4R_1$$

$$\%\text{ Change in Resistance} = \frac{\Delta R}{R} \times 100$$

$$= \frac{4R_1 - R_1}{R_1} \cdot 100 = 300\%$$

11. (*c*) Volume = constant

$$A\ell = C$$

$$\therefore \frac{d\ell}{\ell} + \frac{dA}{A} = 0$$

@FAKE_CBSE_X @RAJ_EDUNET

$\Rightarrow \frac{dA}{A} = \frac{-d\ell}{\ell} = -0.4\%$

Now, $R = \frac{\rho\ell}{A}$

$\therefore \frac{dR}{R} \times 100 = \left(\frac{d\ell}{\ell} - \frac{dA}{A}\right) \times 100$

$= 0.4 - (-0.4) = 0.8\%$

12. [48]

$i = A \times j$

$= \pi\left(R^2 - \frac{R^2}{4}\right) j$

$= \frac{3\pi R^2}{4} \times j$

$= \frac{3\pi \times \left(4 \times 10^{-3}\right)^2}{4} \times 4 \times 10^6$

$= 48\pi$

13. [12]

Given, Current density $J = 1 \times 10^6$ A/m²

$r = 4$ mm $= 4 \times 10^{-3}$ m

$r_1 = \frac{r}{2}$

Formula of current density,

$J = \frac{I}{A} = \frac{I}{\pi r^2 - \pi (r')^2}$

$\therefore I = \pi\left(r^2 - \frac{r^2}{4}\right) \times J$

$= \pi \times \frac{3r^2}{4} \times 1 \times 10^6$

$= \pi \times \frac{3}{4} \times 16 \times 10^{-6} \times 10^6$

$= 12\pi$

$\Rightarrow x = 12$

14. (*a*) Using formula, $R_T = R_0 [1 + \alpha(T - T_0)]$

If $T = 10°C$ and $R_T = 2\ \Omega$ then,

$2 = R_0 [1 + \alpha(10 - T_0)]$ ...(*i*)

If $T = 30°C$ and $R_T = 3\ \Omega$

$3 = R_0 [1 + \alpha(30 - T_0)]$ ...(*ii*)

Solving (*i*) and (*ii*), we get

$\alpha = \frac{1}{30} = 0.033$

15. [144]

We know that, $R = \frac{V}{I} = 1\Omega$

$R = \frac{\rho l}{A} \Rightarrow 1 = \frac{x \times 10^{-3} \times 31.4}{\pi \times (1.2)^2}$

$\Rightarrow x = 144$

16. (*a*)

$R_1 = \rho \frac{L_1}{A_1}$

$R_2 = \rho\left(\frac{3L_1}{A_1/3}\right) = 9\rho \frac{L_1}{A_1}$

$\therefore \frac{R_2}{R_1} = 9$

17. (*a*) Fact based.

18. (*b*) Let x be the length of x.

$\therefore$ Length of $Y = 1 - x$

And, $Rw = 2Ry$

$\Rightarrow \rho\left(\frac{2x}{A/2}\right) = \frac{2\rho(1-x)}{A}$

$\Rightarrow x = \frac{1}{3}$

$\therefore \frac{L_x}{L_y} = \frac{1/3}{1 - 1/3} = \frac{1}{2}$

19. (*d*) $i = \frac{dQ}{dt}$

$dQ = idt$

$\int_0^Q dQ = \int_0^t i\, dt$

$Q = \int_0^{15} \left(\alpha_0 t + \beta t^2\right) dt$

$= \left[\alpha_0 \frac{t^2}{2} + \beta \frac{t^3}{3}\right]_{t=15} - \left[\alpha_0 \frac{t^2}{2} + \beta \frac{t^3}{3}\right]_{t=0}$

$= \left[20 \times \frac{15 \times 15}{2} + 8 \times \frac{15 \times 15 \times 15}{3}\right] - 0$

$= 2250 + 9000$

$= 11250\ C$

20. [5] Given, radius of cylindrical wire, $r = 0.5$ mm, conductivity, $\sigma = 5 \times 10^7$ s/m, Electric field strength, $\vec{E} = 10 \times 10^{-3}$ V/m $= 10^{-2}$ V/m

As we know,

$\therefore I = \sigma EA = 5 \times 107 \times 10\text{–}2 \times \pi \times (0.5 \times 10\text{–}3)2$

$= 125\ \pi$mA $= x3\pi$mA

$\therefore x = 5$

21. (*d*) Relation between current and drift velocity.

$i = ne AV_d$

Number of free ens in per-cubic

$n = \frac{i}{eAV_d}$

$= \frac{10}{1.6 \times 10^{-19} \times 5 \times 10^{-6} \times 2 \times 10^{-3}}$

$= 625 \times 10^{25}$

22. (*c*) $\vec{J} \cdot \vec{A} = I$

$JA\cos 0 = I$

$J = \frac{E}{\rho} = \frac{I}{A\cos 0}$

$E = \frac{I\rho}{A\cos 0} = \frac{5 \times 44 \times 10^{-8}}{0.04 \times \left(\frac{1}{2}\right)}$

$= \frac{5 \times 44 \times 10^{-8} \times 2}{4 \times 10^{-2}}$

$E = 110 \times 10^{-6} = 11 \times 10^{-5} \left(\frac{V}{m}\right)$

23. (*c*) Current throughout the conductor would be constant.

Since, $Vd \propto E$ & $E \propto \frac{1}{r^2}$

So, E increases with decrease in the radius.

Also $Vd \propto E$ So, drift speed increases.

24. (*a*) Resistance of the conductor

$R = R_0 [1 + \alpha \Delta T]$

$\Rightarrow 16 = R_0 [1 + \alpha(15 - 0)]$

$20 = R_0 [1 + \alpha(100 - 0)]$

$\Rightarrow \frac{16}{20} = \frac{1 + \alpha \times 15}{1 + \alpha \times 100}$

$\Rightarrow \alpha = 0.003°C^{-1}$

25. (*b*) Here, resistivity of the four material are given as follows:

rM = 9.8 × 10–8

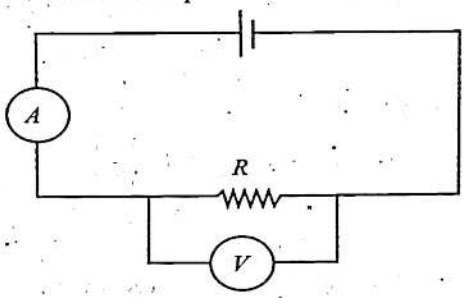
rA = 2.65 × 10–8

rC = 1.724 × 10–8

rT = 5.65 × 10–8

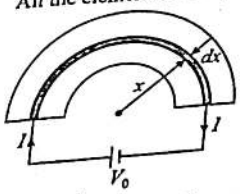
Hence, ρM > ρA > ρC

26. (*c*) In Ohm's law experiment, ammeter is connected in series because in series same current will flow through it. But voltmeter is connected in parallel to resistor to measure the potential difference across it.



@FAKE_CBSE_X_@RAJ_EDUNET

27. (a,c,d)
All the elements are in parallel



$$\therefore \int \frac{1}{dr} = \int_{R_1}^{R_2} \frac{t\,dx}{\rho \pi x}$$

$$\frac{1}{r} = \frac{t}{\pi\rho} \ln\left(\frac{R_2}{R_1}\right)$$

$$\text{Resistance} = \frac{\pi\rho}{t\,\ell n\left(\frac{R_2}{R_1}\right)} \quad ...(i)$$

$\left(-e\vec{E}\right)$ will be inward direction in order to provide centripetal acceleration. Therefore, electric field will be radially outward ...(ii)

$$V_{outer} < V_{inner}$$

$$\frac{mv_d^2}{r} = q\vec{E}$$

$$E = \frac{mv_d^2}{qr} \quad (I = neAv_d \Rightarrow v_d \propto i)$$

$$\Delta V = \int \vec{E}.d\vec{r}$$

$$\Delta V \propto v_d^2$$

$$\Delta V \propto I^2$$

28. (a) Current flows in copper wire,
i = ne AVd
29..5 = 9 × 1023 × 1.6 × 10–19 × 5 × Vd
Vd = 0.02

29. (d) Resistivity, $\rho = \frac{2m}{ne^2\tau}$

$$\rho = \frac{9.1\times10^{-31}}{(25\times10^{-15})\times(1.6\times10^{-19})\times(8.5\times10^{28})}$$

$$= 1.67\times10^{-8}\,\Omega\text{m}$$

30. (d) Here, we have given resistance as a function of temperature, $R(T)$

$$\frac{\frac{1}{T^2}}{\frac{1}{T_0^2}} + \frac{\ln R(T)}{\ln R(T_0)} = 1$$

Now,

$$\Rightarrow \ln R(T) = \ln R(T_0)\left(1 - \frac{T_0^2}{T^2}\right)$$

$$R(T) = R(T_0)e^{-\left(\frac{T_0}{T}\right)^2}$$

Hence, option (d) is correct answer.

31. (b) Mobility, $\mu = \frac{V_d}{E}$ and $E = \rho J$

$$m = \frac{1.1\times10^{-3}}{1.7\times10^{-8}\times\frac{5}{\pi\times25\times10^{-6}}} \approx 1.01\ \text{m}^2/\text{Vs}$$

$$H = \frac{1.1\times10^{-3}\times\pi\times25\times10^{-6}}{1.7\times10^{-8}\times5} \approx 1.01\ \text{m}^2/\text{Vs}$$

32. (d) Resistance between the two sphere

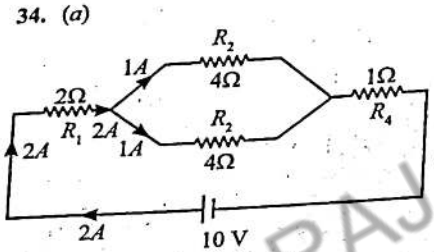
$$R = \int_a^b \frac{\rho dx}{4\pi x^2}$$

$$= \frac{\rho}{4\pi}\left(\frac{1}{a} - \frac{1}{b}\right)$$

33. (a) Each part have resistance $= \frac{R}{5}$

Thus Req. $= \frac{1}{5}\times\frac{R}{5} = \frac{R}{25}$

34. (a)



$$R_{eq} = 2\Omega + 2\Omega + 1\Omega = 5\Omega$$

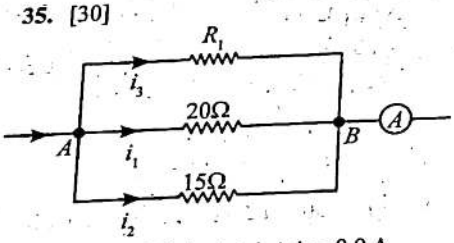
$$i = \frac{V}{R_{eq}} = \frac{10}{5} = 2\text{A}$$

Current in resistance $R_3 = 2 \times \left(\frac{4}{4+4}\right)$

$$= 2\times\frac{4}{8} = 1\text{A}$$

Hence, option (b) is correct answer.

35. [30]



Given, $i_1 = 0.3$ A, $i_1 + i_2 + i_3 = 0.9$ A
So, $V_{AB} = i_1 \times 20\,\Omega = 20 \times 0.3$ V = 6 V

$$i_2 = \frac{6V}{15\,\text{W}} = \frac{2}{5}A$$

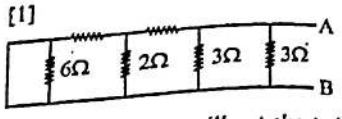
$$i_1 + i_2 + i_3 = \frac{9}{10}A$$

$$\frac{3}{10} + \frac{2}{5} + i_3 = \frac{9}{10}$$

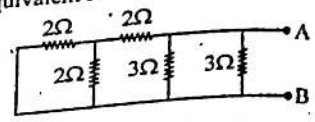
$i_3 = 0.2$ A
So, $i_3 \times R_1 = 6$V
$(0.2)\,R_1 = 6$

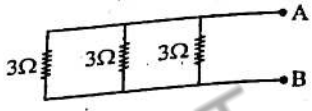
$$R_1 = \frac{6}{0.2} = 30\Omega$$

36. [1]



Resistance 6 ohm will get short circuit, equivalent resistance is





$$R_{eq} = 3\times\frac{1}{3} = 1\Omega$$

37. [5] 10 equal part imply
Each part has resistance = 2Ω
2 parts are connected in parallel so, for parallel contribution

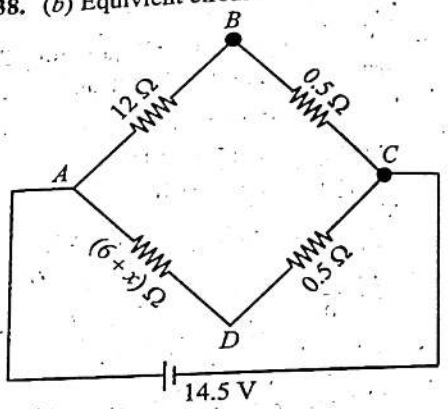
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow \frac{1}{R_{eq}} = \frac{1}{2} + \frac{1}{2}$$

$$R_{eq} = 1\Omega$$

Now, there will be 5 parts each of resistance 1 Ω, they are connected in series.

$$R_{eq} = 5\text{R},\ R_{eq} = 5\Omega$$

38. (b) Equivlent circuit:



Wheatstone Bridge is balanced, therefore,

$$\frac{12}{6+x} = \frac{0.5}{0.5}$$

$$x = 6\,\Omega$$

@FAKE_CBSE_X @RAJ_EDUNET

39. (*d*) Here R_2, R_3, R_4 are in parallel

For parallel combination of resistors,

$$\frac{1}{R_{eq}}=\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}$$

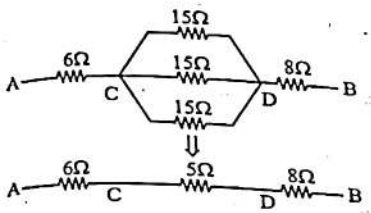
$R_{234}=2\Omega$

R_{234} is in series with R_1 so

$R_{eq}=R_{234}+R_1=2+10=12\Omega$

$i=\frac{12}{12}=1\ Amp$

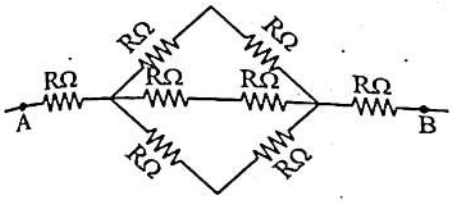
40. (d) Equivalent circuit will become



$\Rightarrow R_{eq}=6\Omega+5\Omega+8\Omega=19\Omega$

41. (*b*)From symmetry we can remove two middle resistance.

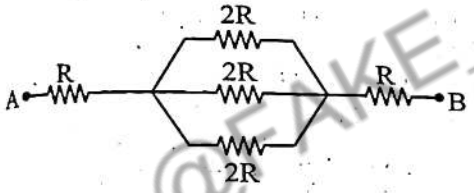
New circuit is



⇓

For series combination of resistor

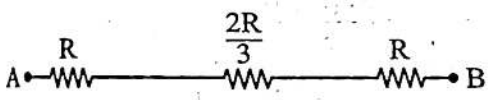
$R_{eq}=R_1+R_2$



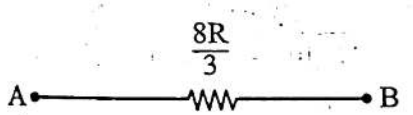
For parallel combination of resistor

$$R_{eq}=\frac{1}{R_1}+\frac{1}{R_2}$$

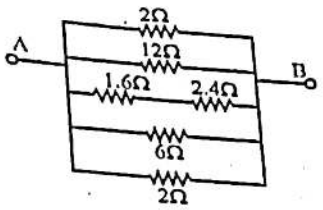
⇓



⇓



42. (*a*) Equivalent circuit can be drawn as



$$\Rightarrow \frac{1}{R_{eq}}=\frac{1}{2}+\frac{1}{12}+\frac{1}{4}+\frac{1}{6}+\frac{1}{2}=\frac{3}{2}$$

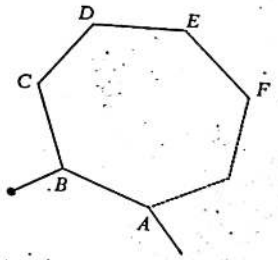
$$\Rightarrow R_{eq}=\frac{2}{3}\Omega$$

43. (*a*) All the resistors are connected in parallel, therefore

$$\frac{1}{R_{eq}}=\frac{1}{10}+\frac{1}{20}+\frac{1}{20}$$

$R_{eq}=5\ k\Omega$.

44. (*a*)



Let resistance of each arm is r,

$\Rightarrow r=R/n$

$$R_{eq(AB)}=\frac{R_1R_2}{R_1+R_2}$$

$$R_{eq}=\frac{r(n-1)r}{r+(n-1)r}\quad R_{eq}=\frac{r(n-1)r}{nr}$$

$$\Rightarrow R_{eq}=\frac{(n-1)R}{n^2}\qquad \left[\because r=\frac{R}{n}\right]$$

45. (*b*) $R_{eq}=R_1+R_2+R_3$

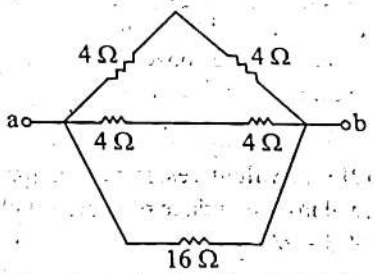
In series, Req is greater than the any resistor present in the circuit

So, Statement-I is false.

Resistivity depends on temperature.

So, Statement-II is False

46. (*b*) Using balanced wheat stones bridge (in 4 Ω network)



$$\Rightarrow R_{eq}=\frac{16\times4}{16+4}=\frac{16}{5}\Omega=3.2\ \Omega$$

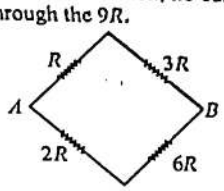
47. (*d*) Equivalent resistance of circuit $R_{eq}=3+1+2+4+2=12\ \Omega$

Current through the battery is $i=\frac{24}{12}=2\ A$

$$I_4=\frac{R_5}{R_4+R_5}\times2=\frac{5}{20+5}\times2=\frac{2}{5}A$$

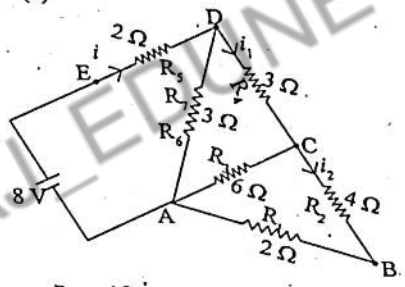
and, $I_5=2-\frac{2}{5}=\frac{8}{5}A$

48. (*d*) As the wheatstone bridge is in balanced condition, no current will flow through the 9*R*.



$$\Rightarrow \frac{1}{R_{eq}}=\frac{1}{4R}+\frac{1}{8R}\Rightarrow R_{eq}=\frac{8R}{3}$$

49. (*d*)

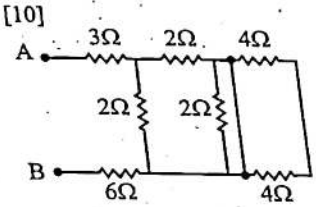


$R_{eq}=4\Omega$

$i=\frac{8}{4}=2A\quad i_1=\frac{2\times3}{3+6}=\frac{2}{3}A$

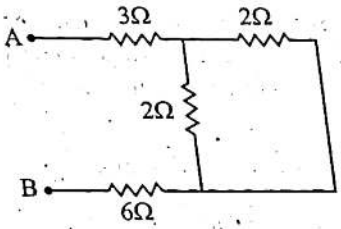
$i_2=\frac{2/3}{2}=\frac{1}{3}A$

50. [10]



Both 4Ω resistance gets short due to the conducting wire parallel to 2Ω.

Removing the 4Ω resistors that have no current.



$R_{eq}=3+(2\,\|\,2)+6=3+1+6$

$\Rightarrow R_{eq}=10\Omega$

@FAKE_CBSE_X @RAILEDUNET

51. [2] $\frac{2}{3}=\frac{\frac{x}{x+1}}{x}$

$\Rightarrow \frac{2}{3}=\frac{1}{x+1}$

$\Rightarrow x=0.5=\frac{1}{2}$

$n=2$

52. [100] Series combination gives maximum resistance whereas parallel combination gives minimum resistance.

$R_{max}=10R, R_{min}=\frac{R}{10}$

$\therefore \frac{R_{max}}{R_{min}}=\frac{10R}{R/10}=100$

53. (b) $R=R_1+R_2$

$\Rightarrow \frac{2\ell}{\sigma A}=\frac{\ell}{\sigma_1 A}+\frac{\ell}{\sigma_2 A} \Rightarrow \sigma=\frac{2\sigma_1\sigma_2}{\sigma_1+\sigma_2}$

54. [4] Formula of resistance, $R=\frac{r\ell}{A}$

Equivalent resistance of eight wire in parallel is R/8

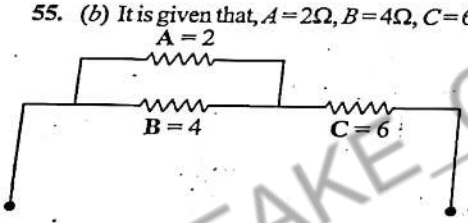
According to question,

$R=\frac{\rho\ell}{\pi\left(\frac{d}{2}\right)^2} \Rightarrow R\propto\frac{\ell}{d^2}$

$\frac{R_1}{R_2}=\frac{\ell_1}{\ell_2}\cdot\frac{d_2^2}{d_1^2}$

$\frac{R}{R}=\frac{\ell}{2\ell}\cdot\frac{d^2}{d^2} \Rightarrow d_2=4d$

55. (b) It is given that, $A=2\Omega, B=4\Omega, C=6\Omega$,



From the diagram given above,

$R_{eq}=\frac{2\times4}{2+4}+6=\frac{8}{6}+6=\frac{4}{3}+6$

$\therefore R_{eq}=\frac{22}{3}\Omega$

56. (a) Arrangement of the resistens is equivalent to wheat stone bridge. Therefore equivalent resistance of the circuit.

$R_{eq}=\frac{4\times4}{4+4}+\frac{4\times4}{4+4}=4\Omega$

From ohm's law

$I=\frac{V}{R}=\frac{40}{4}=10A$

57. (a) Statement–1

$80=\frac{\rho\ell}{A}$

$R'=\frac{\rho\ell}{4A}=\frac{80}{4}=20\Omega$

So, $R_{eq}=\frac{R'}{4}=\frac{20}{4}=5\Omega$

Statement–II

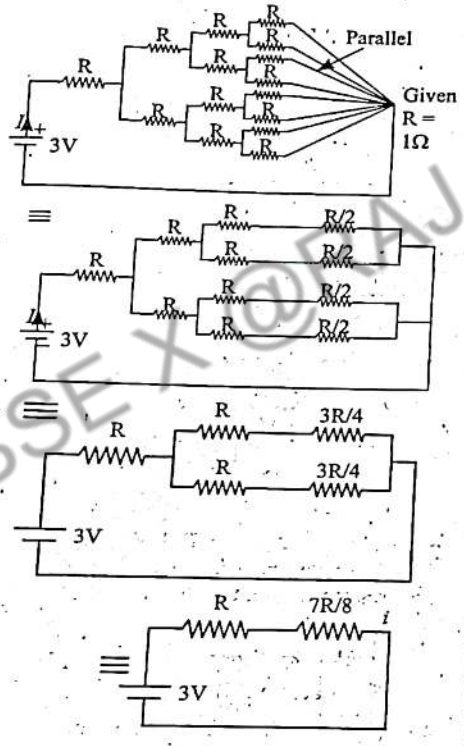
$\frac{P_1}{P_2}=\frac{V^2}{2R}\times\frac{3R}{V^2}=\frac{3}{2}$

58. (a) The circuit is balanced whetstone bridge. So there is no current in 5Ω resistor.

$\Rightarrow R_{eq}=\frac{6\times12}{6+12}+2=6\Omega$

$\Rightarrow I=\frac{V}{R_{eq}}=\frac{6}{6}=1A$

59. [8]



Current, $I=\frac{3\times8}{15R}=\frac{8}{5R}$

On comparing above result with $I=a/5$, we get

$a=8$

60. [2] Equivalent resistance of parallel combination of three resistors = 3 ohm, I = 6/3 = 2A

61. [3] Equivalent resistance of the circuit

$Req=\frac{ma}{3}+\frac{a}{2m}$

$\frac{dR_{eq}}{dm}=0 \Rightarrow \frac{a}{3}-\frac{a}{2}m^2=0$

$m2=\frac{3}{2} \Rightarrow m=\sqrt{\frac{3}{2}}$

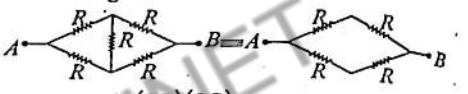
$x=3$

62. (c) Using hit and trial method, from option (c) we get,

$R_{eq}=\frac{2\times4}{2+4}+6+8=\frac{46}{3}\Omega$

63. (b) As, 5 Ω is connected across conductor so we can remove it. $Req=\frac{3\times\frac{3}{2}}{3+\frac{3}{2}}=1\Omega$

64. (b) Given circuit can be re-drawn and it becomes case of balanced Wheatstone bridge



$R_{AB}=\frac{(2R)(2R)}{2R+2R}=R$

65. (a) $R_1=\rho_1\frac{\ell}{A}$ $R_2=\rho_2\frac{\ell}{A}$

Equivalent resistance in parallel form.

$\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}=\frac{A}{\ell}\left[\frac{1}{\rho_1}+\frac{1}{\rho_2}\right]$

$=\frac{3\times10^{-6}}{\frac{1}{4}}\left[\frac{1}{1.7\times10^{-8}}+\frac{1}{2.6\times10^{-8}}\right]$

$=12\times10^{+2}\left(\frac{10}{17}+\frac{10}{26}\right)$

$R=0.858\times10^{-3}\ \Omega$

66. (d) Formula of resistance, $R=\frac{\rho l}{A}$

$\rho_1=12\mu$ cm

$\rho_2=51\mu$ cm

Equivalent resistance, $\frac{R_1R_2}{R_1+R_2}=3$

$\frac{\left(\rho_1\frac{\ell}{A}\right)\left(\rho_2\frac{\ell}{A}\right)}{\left(\frac{\rho_1\ell}{A}\right)+\left(\frac{\rho_2\ell}{A}\right)}=3$

$\ell=\frac{3A(\rho_1+\rho_1)}{\rho_1\rho_2}$

$=\frac{3\times\left[\frac{\pi}{4}\times\left(2\times10^{-3}\right)^2\right][12+51]\times10^{-6}\times10^{-2}}{12\times10^{-6}\times10^{-2}\times51\times10^{-6}\times10^{-2}}$

$=97$m

@FAKE_CBSE_X@RAJ_EDUNET

67. (b) $\frac{1}{R_{eq}}=\frac{1}{R_1}+\frac{1}{R_2}=\frac{1}{4}+\frac{1}{4}$

$\Rightarrow Req=2$

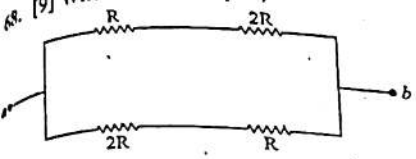
$\frac{\Delta R_{eq}}{R_{eq}^2}=\frac{\Delta R_1}{R_1^2}+\frac{\Delta R_2}{R_2^2}$

$\frac{\Delta R_{eq}}{4}=\frac{0.8}{16}+\frac{0.4}{16}=\frac{1.2}{16}$

So, $\Delta Req=0.3$

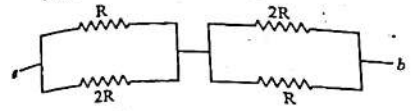
$\therefore Req=(2\pm 0.3)\Omega$

68. [9] When switch is open,



$R_{ab}=\frac{3R}{2}$

When switch is closed,



$R'_{ab}=2\times\frac{R\times 2R}{R+2R}=\frac{4R}{3}$

$\frac{R_{ab}}{R'_{ab}}=\frac{3R/2}{4R/3}=\frac{9}{8}=\frac{x}{8}\Rightarrow x=9$

69. [6] Equivalent resistance, $Req=6\ \Omega$

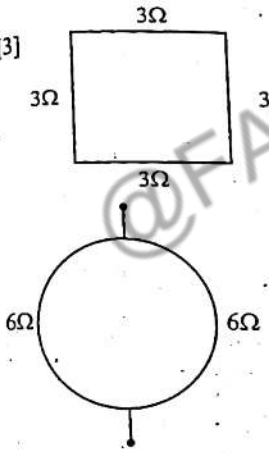
Current through the battery,

$i=\frac{12V}{6\Omega}=2A$

Voltage across, 15 Ω resistance, V (15Ω)

$=6V$

70. [3]



$R_{AB}=\frac{6\times 6}{12}=3$

71. [3] $Req=5+1+1=7k\Omega$

$\therefore I=\frac{V_{eq}}{R_{eq}}=\frac{21}{7\times 10^3}=3mA$

72. [70]

$R_{eq}=10+\frac{50\times 20}{50+20}=\frac{170}{7}\Omega$

$\Rightarrow I=\frac{170}{\frac{170}{7}}=7A$

$\Rightarrow x=10\times 7=70\ V$

73. [2] Using KCL at P, $I_1+I_2=6$ ...(I)

and using KVL in closed circuit $PQRP$,

Solving above equations, we get, $I_1=2A$.

74. [20]

In series connection, $R_{eq}=nR=10n$

$\Rightarrow I_{se}=\frac{20}{10+10n}=\frac{2}{1+n}$

In parallel connection, $R_{eq}=\frac{10}{n}$

$\Rightarrow I_p=\frac{20}{\frac{10}{n}+10}=\frac{2n}{1+n}$

According to the question,

$\Rightarrow \frac{I_p}{I_{se}}=20=\frac{2n/1+n}{2/1+n}\Rightarrow n=20$

75. [4] In parallel combination,

$R_{eq}=\frac{R_1R_2}{R_1+R_2}$

$\Rightarrow \frac{\rho\ell}{2A}=\frac{\rho_1\frac{\ell}{A}\times\rho_2\frac{\ell}{A}}{\rho_1\frac{\ell}{A}+\rho_2\frac{\ell}{A}}\quad\left(\because R=\rho\frac{l}{A}\right)$

$\Rightarrow \frac{\rho}{2}=\frac{6\times 3}{6+3}=2$

$\Rightarrow \rho=2\times 2=4\Omega-cm$

76. [4] $s=np$

$R_1+R_2=n\left[\frac{R_1R_2}{R_1+R_2}\right]$

$\Rightarrow R_1^2+R_2^2+2R_1R_2=nR_1R_2$

$\Rightarrow R_1^2+(2-n)R_1R_2+R_2^2=0$

For real roots, $b^2-4ac\geq 0$

$[(2-n)R_2]^2-4\times 1\times R_2^2\geq 0$

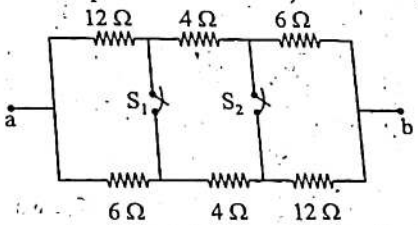
$\Rightarrow (2-4)^2R_2^2\geq 4R_2^2\Rightarrow 2\times n\geq\pm 2$

$\Rightarrow 2-n\geq -2\Rightarrow n\geq 4$

So, minimum value for $n=4$

77. [10]

The equivalent resistance,



$R_{eq}=(12\|6)+(4\|4)+(4\|12)$

$=\left(\frac{12\times 6}{18}\right)+\left(\frac{4\times 4}{8}\right)+\left(\frac{6\times 12}{18}\right)$

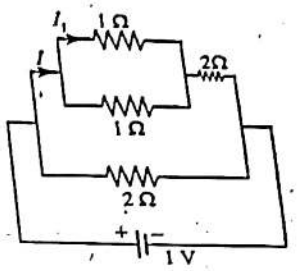
$=4+2+4=10\Omega$

78. (c) Resistance in parallel

$=\frac{R_1R_2}{R_1+R_2}=\frac{1}{2}\Omega$

Now, resistance in series R'

$=\frac{1}{2}+2=2.5\Omega$

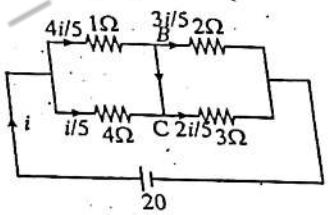


Current through upper breach

$I=\frac{1}{2.5}=0.4A$

Current through $1\Omega\ (I_1)=\frac{I}{2}=0.2A$

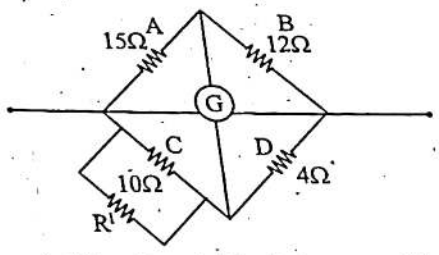
79. (b) $R_{eff}=\frac{4}{5}+\frac{6}{5}=2\Omega$



$i=\frac{20}{2}=10A$

$I=\frac{4i}{5}-\frac{3i}{5}=+\frac{i}{5}=2A$

80. [10]



Wheatstone bridge balance conditions

$\frac{A}{B}=\frac{C}{D}$

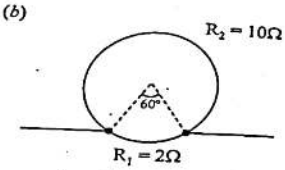
$\Rightarrow \frac{10R'}{10+R'}\times 12=15\times 4$

On solving

$R'=10\ W$

@FAKE_CBSE_X @RAJ_EDUNET

81. *(b)*



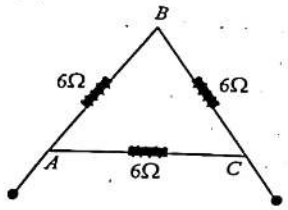
$\Rightarrow R = \frac{\rho\ell}{A} = \frac{\rho\ell^2}{V} \quad R \propto \ell^2$

$R = 12\Omega$ (new resistance of wire)

$R_1 = 2\Omega, R_2 = 10\Omega$

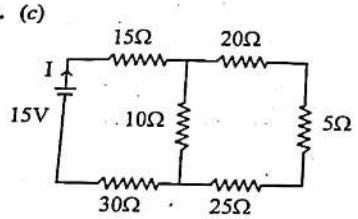
$R_{eq} = \frac{10\times2}{10+2} = \frac{5}{3}\Omega$

82. *(a)*



So, $R_{AC} = \frac{12\times6}{18} = 4\Omega$

83. *(c)*

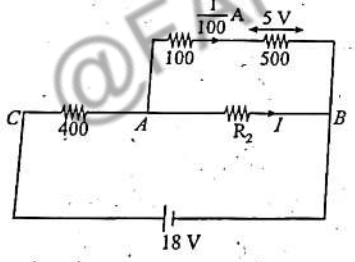


$Req = 15 + \{(20+5+25) \parallel 10\} + 30$

$Req = 15 + \frac{25}{3} + 30 = \frac{160}{3}$

Current, $I = \frac{E}{R_{eq}} = \frac{15}{\left(\frac{160}{3}\right)} = \frac{9}{32}$ amp

84. *(a)*



$V_{AB} = \left(\frac{1}{100}\right) 600 = 6$ volt

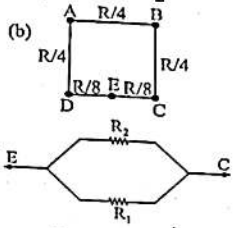
$\Rightarrow V_{AC} = 18\ V - 6\ V = 12$ volt

$I_{AC} = \frac{12}{400} = \frac{3}{100} \Rightarrow I = I_{AC} - \frac{1}{100}$

$\Rightarrow I = \frac{3}{100} - \frac{1}{100} = \frac{2}{100}$

$\Rightarrow R_2 = \frac{V_{AB}}{I} = \frac{6\times100}{2} = 300\Omega$

85. (b)



$R1 = \frac{R}{8}, R2 = \frac{R}{8} + \frac{R}{4} + \frac{R}{4} + \frac{R}{4} + \frac{R}{4} = \frac{7R}{8}$

$\frac{1}{R_{EC}} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{R_{EC}} = \frac{8}{7R} + \frac{8}{R}$

$REC = \frac{7R}{8+56} = \frac{7R}{64}$

86. *(d)* $\frac{v^2}{R} = W$ ...*(i)*

When the wire is cut into two halves

$\frac{v}{\frac{1}{2}\left(\frac{R}{2}\right)} = W'$ ...*(ii)*

From *(i)* & *(ii)*, we get

$W' = 4W$

87. *(c)*Power, $P = i^2R$

$P_{int} = I_{int}^2 R$

$P_{final} = (0.8\ I_{int})^2 R$

% change in power =

$= \frac{P_{final} - P_{int}}{P_{int}} \times 100$

$= (0.64 - 1) \times 100 = -36\%$

88. [3]Equivalent Resistance,

$R_{eq} = \frac{4}{3}\Omega$

We know, $P = \frac{V^2}{R_{eq}} = \frac{4}{4/3} = 3W$

89. (1) Resistance,

$R = \frac{V^2}{P} = \frac{(200)^2}{50} = \frac{40000}{50}$

$R = 800$

Power dissipated

$P = \frac{\left(V_{applied}\right)^2}{R} = \frac{(100)^2}{800} = 12.5$ watt

90. (b) The current through 5Ω resistor is I_1 and 10 Ω resistor is I_2

$\frac{I_1}{I_2} = \frac{10}{5} = \frac{2}{1}$

$\frac{P_1}{P_2} = \frac{I_1^2 R_1}{I_2^2 R_2} = \left(\frac{2}{1}\right)^2 \times \frac{5}{10} = \frac{2}{1}$

91. (c) Resistance of the material, $R = \frac{\rho\ell}{A}$,

Now, $P = \frac{v^2}{R} \Rightarrow P \propto \frac{1}{\ell}$

$\Rightarrow \frac{P_1}{P_2} = \frac{t_2}{t_1} = \frac{15}{20} = \frac{\ell_2}{\ell_1}$

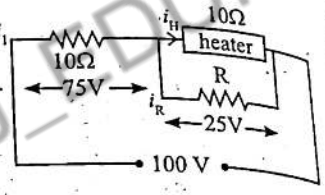
$\therefore \ell_2 = \frac{3}{4}\ell_1$

92. [5] Resistance of the heater,

$R_{heater} = \frac{V^2}{P} = \frac{(100)^2}{1000} = 10\Omega$

For heater, $P_{heater} = \frac{V^2}{R} \Rightarrow V = \sqrt{PR}$

$V = \sqrt{62.5\times10} \Rightarrow V = 25v$



$i_1 = \frac{75}{10} = 7.5\ A, i_H = \frac{25}{10} = 2.5\ A$

$i_R = i_1 - i_H = 5$

Using ohm' law, V = IR

$\therefore R = \frac{25}{5} = 5\Omega$

93. *(b)* $H = I2Rt = 42R \times 10 = 160R$

$H' = I'2Rt = 162R \times 10 = 2560R = 16H$

94. (d) The formula of power $P = I2R_{eq}$

$\Rightarrow P \propto Req$

$R_A = \frac{3R}{2}, R_B = \frac{2R}{3}, R_C = \frac{R}{3}, R_D = 3R$

95. *(a)* Heat energy produced in a resistor R connected to potential difference V is

$H = \frac{V^2}{R} \times t$

As the resistors are connected in parallel

$\Rightarrow \frac{H_1}{H_2} = \frac{\frac{V^2t}{R}}{\frac{V^2t}{3R}} = 3:1$

(a) Parallel

Heat produced $H_p = \left[\frac{V^2}{\left(\frac{R}{2}\right)}\right] t = \frac{2V^2t}{R}$

Series combination, R_{eq} =

Heat produced $H_s = \left($

$\frac{H_p}{H_s} = 4$ [Dividing (

[16] *Initial* $P_1 = \frac{V_0^2}{R}$

After cutting wire in

$R' = \frac{R}{2}$

$\because R = \frac{\rho l}{A}$

$\therefore P_2 = \frac{V_0^2}{R'} \times 2 = \frac{V_0}{}$

$\frac{P_2}{P_1} = 4 = \frac{\sqrt{x}}{1} \Rightarrow$

[14] $\frac{v_1}{v_2} = \frac{R_1}{R_2} = \frac{P_2}{P_1} =$

$v_1 = \frac{3}{8} \times 220 =$

$\therefore P_1' = \left(\frac{V_1}{V}\right)^2$

[450]

$H = i^2Rt$

$300 = 2^2 \times R$

$\Rightarrow R = 300$

Now, for i

$H = 3^2 \times 5$

(a, b, c) V

equivalent

$R_{C_1} = \frac{16}{11}$

Equivale

$R_{C_2} = \frac{6}{1}$

For volt

$P =$

P

$R_{}$

$=$

@FAKE_CBSE_X @RAJ_EDUNET

96. (a) Parallel combination, Req = $\frac{R}{2}$

Heat produced

$$H_p = \left[\frac{V^2}{\left(\frac{R}{2}\right)}\right]t = \frac{2V^2t}{R} \quad \ldots (i)$$

Series combination, $R_{eq} = 2R$

Heat produced $H_s = \left(\frac{V^2}{2R}\right)t$ ... (ii)

$\therefore \frac{H_p}{H_s} = 4$ [Dividing (i) and (ii)]

97. [16]

Initial $P_1 = \frac{V_0^2}{R}$

After cutting wire into two half

$R' = \frac{R}{2}$

$\because R = \frac{\rho l}{A}$

$\therefore P_2 = \frac{V_0^2}{R'} \times 2 = \frac{V_0^2}{R} \times 4 \Rightarrow P_2 = P_1 \times 4$

$\frac{P_2}{P_1} = 4 = \frac{\sqrt{x}}{1} \Rightarrow x = 16$

98. [14]

$\frac{v_1}{v_2} = \frac{R_1}{R_2} = \frac{P_2}{P_1} = \frac{60}{100} = \frac{3}{5}$

$v_1 = \frac{3}{8} \times 220 = 3 \times 27.5 = 82.5V$

$\therefore P_1' = \left(\frac{V_1}{V}\right)^2 P = \left(\frac{330}{4 \times 220}\right)^2 \times 100 = 14W$

99. [450]

$H = i^2Rt$

$300 = 2^2 \times R \times 15$

$\Rightarrow R = 300/60 = 5\Omega$

Now, for $i = 3A, t = 10s, R = 5\Omega$

$H = 3^2 \times 5 \times 10 = 450$ J

100. (a, b, c) When both switches are open equivalent resistance in circuit 1

$R_{C_1} = \frac{16}{11}\Omega$

Equivalent resistance in circuit 2

$R_{C_2} = \frac{6}{11}\Omega$

For voltage source

$P = \frac{V^2}{R}$

$P \propto \frac{1}{R}$

$R_{C_1} > R_{C_2}$

$\Rightarrow P_2 > P_1$ (Option (a) correct)

For constant current source

$P = i^2R$

$P \propto R$

$\Rightarrow P_1 > P_2$ (Option (b) correct)

When switch is closed

$R'_{C_1} = \frac{5}{11}\Omega$

$R'_{C_2} = \frac{1}{2}\Omega$

$R'_{C_1} < R_{C_1}$

For voltage source

$P \propto \frac{1}{R} \Rightarrow Q_1 > P_1$ (Option (c) correct).

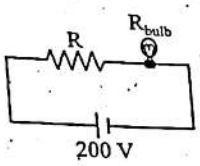
and $R'_{C_1} > R'_{C_2}$

For current source $P \propto R$

Q2 > Q1 (Option (d) also incorrect)

101. (a) $R_{bulb} = \frac{V^2}{P_{bulb}} = \frac{100 \times 100}{500} = 20\ \Omega$

$I = \frac{V_{supply}}{R_{bulb} + R} = \frac{200}{20 + R}$



According to the question.

Power delivered by bulb = 500 W

$\Rightarrow$ I2 Rbulb = 500

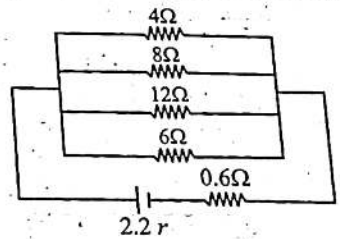
$\Rightarrow \left(\frac{200}{20 + R}\right)^2 \times 20 = 500$

$\Rightarrow (R + 20)^2 = \frac{200 \times 200 \times 20}{500} = 1600$

$\Rightarrow R + 20 = 40$

$\backslash R = 20$ W

102. (a) Equivalent resistance of the circuit.



$= 0.6\Omega + \frac{3 \times \frac{48}{14}}{3 + \frac{48}{14}}\Omega$

$= 0.6\Omega + \frac{(144/14)\Omega}{\left(\frac{90}{14}\right)}$

$= 0.6\Omega + 1.6\Omega = 2.2\Omega$

Power dissipated in the circuit

$P = \frac{V^2}{R_{eq}} = \frac{(2.2V)^2}{2.2\Omega} = 2.2$ W

103. (d) From first law of thermodynamics

$\Delta U = \Delta Q - \Delta W$

$\frac{\Delta U}{\Delta t} = \frac{\Delta Q}{\Delta t} - \frac{\Delta W}{\Delta t} = \frac{6000}{60} - 90 = 10$J

$t = \frac{\Delta U}{10} = \frac{2.5 \times 10^3}{10} = 2.5 \times 10^2$ seconds

104. (a) Using Joule's law of heating, heat generated in the resistance

H = I2RT

H1 = 500 = (1.5)2 R(20)

$H_2 = (3)^2 R(20) \Rightarrow H_2 = H_1 \times \left(\frac{3}{1.5}\right)^2$

$= 500 \times \frac{9}{2.25} = 2000$ J

105. [3840] $E = I2Rt$

$\Rightarrow 192 = (4)2R(1)$

$\Rightarrow R = 12\ \Omega$

As current is doubled and time = 5s

So, energy dissipated in this case E' = 3840 J

106. [4] In first condition $R1 = 36\Omega$

In second condition $R2 = 18\Omega$

$P_1 = \frac{V^2}{R_1} = \frac{(240)^2}{36}$

$P_2 = \frac{V^2}{R_2} + \frac{V^2}{R_2} = \frac{(240)^2}{18} + \frac{(240)^2}{18}$

$P_2 = \frac{(240)^2}{9}$

$\Sigma o \frac{P_1}{P_2} = \frac{(240)^2/36}{(240)^2/9} = \frac{1}{4} \quad x = 4$

107. [2500] Energy dissipated by a resistor

H = i² Rt

$R = \frac{10 \times 10^{-3}}{\left(2 \times 10^{-3}\right)^2 \times 1} = 2500\Omega$

Hence, the resistance is 2500 W

108. [50].

Given, P = 20W, Supply voltage, VS = 200V

Resistance of electric Bulb,

$R_B = \frac{V^2}{P} = \frac{(100)^2}{200} = 50\Omega$

Formula of power,

$P = I2RB$

$= \left(\frac{V_S}{R + R_B}\right)^2 . R_B$

$\Rightarrow \left(\frac{200}{R + 50}\right)^2 \times 50 = 200$

$R = 50\Omega$]

@TAKE_CBSE_X @RAJEDUNET

109. (b) Total power consumed (P) is = (15×45)+ (15 × 100) + (15 × 10) + (2 × 1000) = 4325 W.
So, current (I)

$$= \frac{\text{Power consumed}}{\text{Voltage supplied}} = \frac{4325}{220} = 19.66A$$

Hence, answer is 20 Amp.

110. (c) Power in external $R = \left(\frac{\varepsilon}{r+R}\right)^2 R$

This power is maximum, when R = r.

$$r = \int_a^b \rho \frac{dx}{2\pi x l}$$

$$r = \frac{\rho}{2\pi l} \ln \frac{b}{a}$$

111. (a) $i^2R = 0.5$

$iR = 2.5$

$\Rightarrow i = 0.2$ A and

$R = 12.5\ \Omega$

$V = \varepsilon - ir$

$2.5 = 3.0 - 0.2\,r$

$\Rightarrow r = 2.5\ \Omega$

Power dissipated in internal resistance

$$P_r = \frac{P_R}{R/r} = \frac{0.5}{5} = 01W = i^2 r = 0.1\ W$$

112. (a) $R_{eq} = (4R \| 4R) + R + (6R + 12R) + R$

$R_{eg} = 8R$

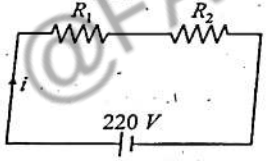
$$\because p = \frac{V^2}{R_{eg}} = \frac{(16)^2}{8R} = 4$$

$\therefore R = 8\Omega$

113. (a) Resistance, $R = \frac{V^2}{P}$

$$\Rightarrow R_1 = \frac{(200)^2}{25} = 1936\ \Omega$$

$$R_2 = \frac{(200)^2}{100} = 484\ \Omega$$



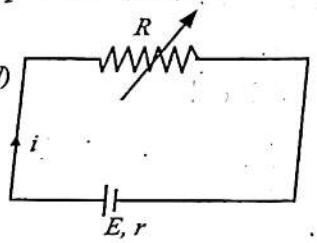
$$i = \frac{220}{R_1 + R_2} = \frac{1}{11} A = 0.09A$$

Dissipated powers,

$P_1 = i2R1 = (0.09)2\ 1936 = 16W$

$P_2 = i2R2 = (0.09)2\ 484 = 4W$

114. (d)



Internal resistance = r
External resistance = R
For maximum power delivered by cell
Internal resistance = External resistance
$\Rightarrow r = R$

115. (a) $R = \frac{P}{I^2} = \frac{4.4}{4\times10^{-6}} \mu = 1.1\times10^6\ \Omega$

$$P' = \frac{V^2}{R} = \frac{(11)^2}{1.1\times10^6} = 11\times10^{-5}\ \text{W}$$

116. (b) When resistances are connected in parallel.

$$P_T = \frac{P_1 P_2}{P_1 + P_2} = 60$$

$\because P1 = P2$

$\therefore P1 = P2 = 120$ W

So total consumed power

$P' = P1 + P2 = 120 + 120 = 240$ W

117. (b) $Q = P \times t$

$Q = mc\Delta T + mL$

$$P = \frac{V_{rms}^2}{R}$$

$$4200 \times 80 + 2260 \times 10^3 = \frac{(200)^2}{20} \times t$$

$\Rightarrow t = 1298$ sec $= 21.6$ min

$t \simeq 22$ min

118. (a) By colour coding,

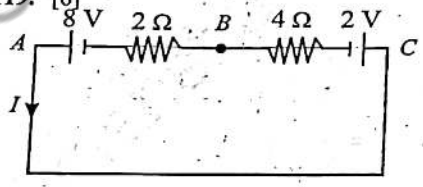
$R = 50 \times 10^2\ \Omega$

$I^2R = P$

The maximum current which can be passed through the resistor

$$I = \sqrt{\frac{P}{R}} = 20mA$$

119. [6]



Current through the circuit,

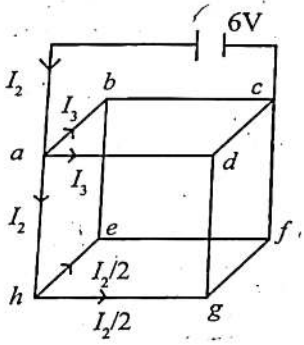
$$I = \frac{8-2}{2+4} = \frac{6}{6} = 1\ \text{A}$$

Applying Kirchhoff from C to B

$V_C - 2 - 4 \times 1 = V_B$

$V_C - V_B = 6$V

120. (1)



From symmetry, current through $e-b$ & $g-d = 0$

$$\therefore R_{eq} = \frac{3}{4} \times R = \frac{3}{2}\Omega$$

Current through battery

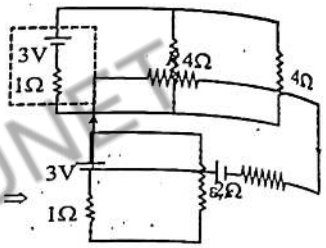
$$= \frac{6\times2}{3} = 4A$$

and $I_2 = \frac{4}{8} \times 2 = 1A$

$\therefore \Delta V$ across e–f

$$= \frac{I_2}{2} \times R = \frac{1}{2} \times 2 = 1V$$

121. (a)



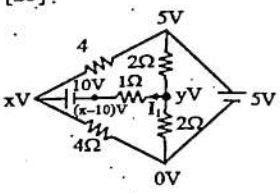
Using ohm's law, $V = IR$

Current in the circuit, $i = \frac{3}{1+2} = 1A$

$v = E - ir$

$= 3 - 1 \times 1 = 2V$

122. [25]



Applying KCL,

$$\frac{y-5}{2} + \frac{y-0}{2} + \frac{y-x+10}{1} = 0$$

$y - 5 + y + 2y - 2x + 20 = 0$

$4y - 2x + 15 = 0$ ...(i)

$$\frac{x-5}{4} + \frac{x-0}{4} + \frac{x-10-y}{1} = 0$$

$x - 5 + x + 4x - 40 - 4y = 0$

$6x - 4y - 45 = 0$ ...(ii)

From equation (i) and (ii), we get

$x = \frac{15}{2}$ & $4y - 15 + 15 = 0$

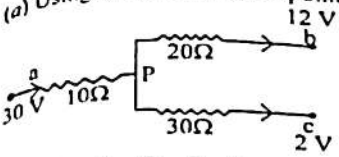
$y = 0$

$$\therefore i = \frac{y-x+10}{1} = \frac{0-7.5+10}{1}$$

$$\Rightarrow i = 2.5\,A = \frac{n}{10} A \Rightarrow n = 25$$

@FAKE_CBSE_@RAJ_EDUNET

123. (a) Using kirchhoff's law at point P.



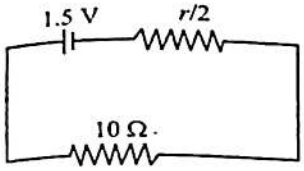
$$\frac{P-30}{10}+\frac{P-12}{20}+\frac{P-2}{30}=0$$

$$P\left(\frac{1}{10}+\frac{1}{20}+\frac{1}{30}\right)=\frac{30}{10}+\frac{12}{20}+\frac{2}{30}$$

$$P\left(\frac{6+3+2}{60}\right)=\frac{108+36+4}{60}=20V$$

$$\therefore I_{20\Omega}=\frac{x-12}{20}=\frac{20-12}{20}=0.4A$$

124. (c)



$$E_{eq}=\frac{\frac{E_1}{r_1}+\frac{E_2}{r_2}}{\frac{1}{r_1}+\frac{1}{r_2}}=\frac{\frac{F}{r}+\frac{E}{r}}{\frac{1}{r}+\frac{1}{r}}$$

$$=\frac{\frac{2E}{r}}{\frac{2}{r}}=\frac{\frac{2E}{r}}{\frac{2}{r}}=E$$

$$r_{eq}=\frac{r_1r_2}{r_1+r_2}=\frac{rr}{2r}=\frac{r}{2}$$

$Eeq = E = 1.5$ V

$$r_{eq}=\frac{r}{2}$$

$$\therefore V=E-\frac{ir}{2}\quad 1.2=1.5-\frac{ir}{2}\quad \frac{ir}{2}=0.3$$

Again,

$$E_{eq}-i'10-\frac{ir}{2}=0$$

$$\frac{1.5}{10+\frac{r}{2}}=i$$

$$10i+\frac{ir}{2}=1.5$$

$$10i+0.3=1.5\Rightarrow i=0.12\text{ A}$$

$$\therefore r=\frac{0.6}{0.12}=5\ \Omega$$

125. (a) We have,

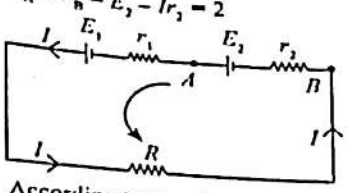
$$E_1=E_2=E$$

$$\therefore I=\frac{V_{net}}{R_{net}}=\frac{2E}{R+r_1+r_2}$$

Potential drop across second cell is

$$V_A-E_2+Ir_2=V_B$$

$$V_A-V_B=E_2-Ir_2=2$$



According to question $V_A - V_B = 0$

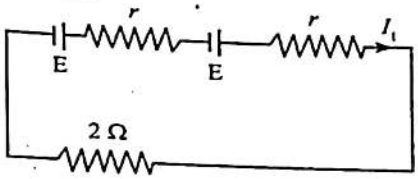
$$E_2-Ir_2=0$$

$$\Rightarrow E-\left(\frac{2E}{R+r_1+r_2}\right)r_2=0$$

$$\Rightarrow R+r_1-2r_2=0$$

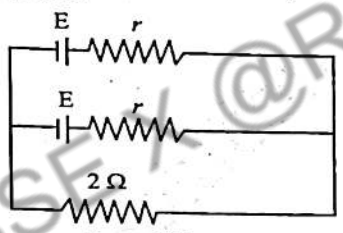
$$\Rightarrow R=r_2-r_1$$

126. (a) **Case I:** when the cells are connected in series.



$$I_1=\frac{2E}{2r+2}\qquad ...(i)$$

Case II: when the cells are connected in parallel



$$I_2=\frac{E}{\frac{r}{2}+2}=\frac{2E}{r+4}\qquad ...(ii)$$

According to the question, $I1 = I2$

From (i) and (ii),

$$\frac{2E}{2r+2}=\frac{2E}{r+4}\Rightarrow\frac{2}{2r+2}=\frac{2}{r+4}$$

$$\Rightarrow 2r+2=r+4$$

$$\Rightarrow r=2\ \Omega$$

127. (d) Equivalent resistance of the circuit.

$$R_{eq}=5+\frac{10\times5}{10+5}+10=\frac{55}{3}k\Omega$$

From Ohm's law,

$$V_{AB}=R_{eq}I$$

$$=\left(\frac{55}{3}\times10^3\right)\times\left(15\times10^{-3}\right)=275\text{ V}$$

128. (d) $r_{eq}=r_1+r_2+R$

$$\therefore I=\frac{2E}{r_1+r_2+R}$$

According to the question,

$$-(V_A-V_B)=E-Ir_2$$

$$0=E-Ir_2$$

$$E=Ir_2$$

$$E=\frac{2E}{r_1+r_2+R}r_2$$

$$r_1+r_2+R=2r_2$$

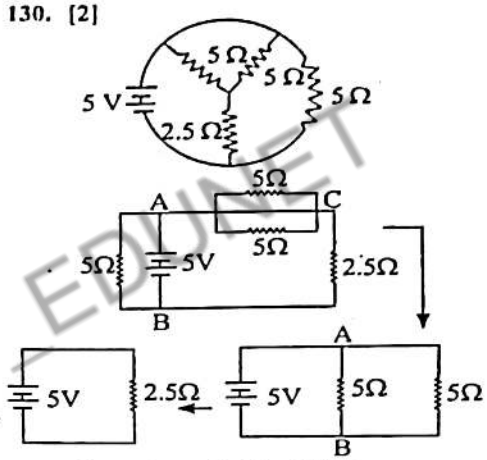
$$\therefore R=r_2-r_1$$

129. [4] From Nodal analysis,

$$\frac{V_0-2}{1k\Omega}+\frac{V_0-4}{1k\Omega}+\frac{V_0-6}{1k\Omega}=0$$

$$V_0=4\text{ V}$$

130. [2]



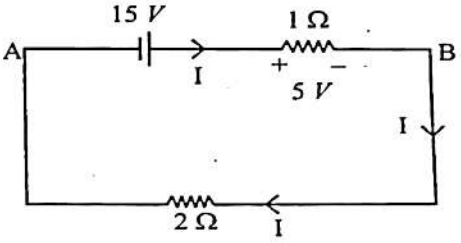
Current supplied by 5V battery

$= 5\text{ V} / 2.5\Omega = 2\text{ A}$

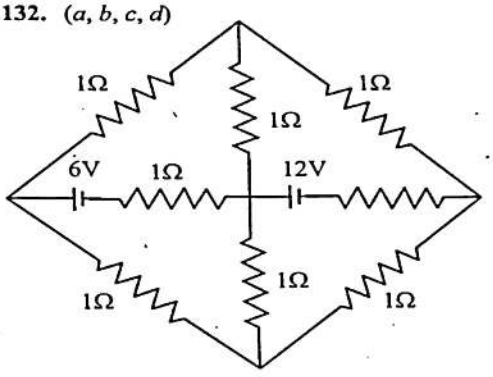
131. [10] $I=\frac{15}{3}=5A$

$\therefore VAB = 15V - 5 \times 1\ V$

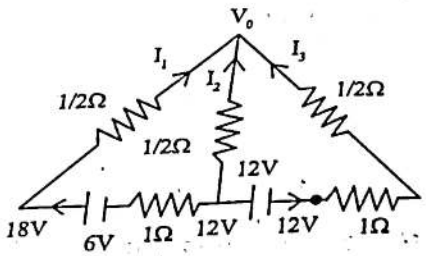
$= 15V - 5V = 10\ V$



132. (a, b, c, d)



@FAKE_CBSE_X @RAJ_EDUNET



From KCL

$I_1 + I_2 + I_3 = 0$

$\Rightarrow \frac{18-V_0}{3/2} + \frac{12-V_0}{1/2} + \frac{0-V_0}{3/2} = 0$

$\Rightarrow 18 - V_0 + 36 - 3V_0 - V_0 = 0$

$\Rightarrow 54 = 5V_0$

$\frac{2\left(\frac{54}{5} - v'\right)}{1} + \frac{18 - v'}{1} = 0$

$\frac{108}{5} + 18 = 3v'$

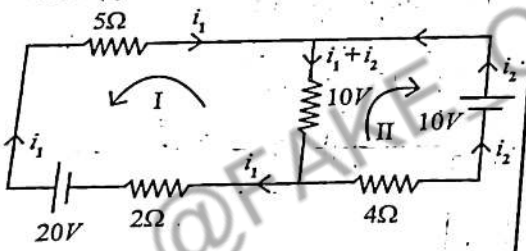
$I_{R_1} = \frac{36}{5} = 7.2\,A$

$I_{R_2} = \frac{6}{5} = 1.2\,A$

$I_{R_3} = \frac{24}{5} = 4.8\,A$

$I_{R_4} = \frac{12}{5} = 2.4\,A$

133. (c)



Loop-I:

$-20 + 2i_1 + 10(i_1 + i_2) + 5i_1 = 0$

$17i_1 + 10i_2 = 20$ ...(i)

Loop-II:

$-10 + 4i_2 + 10(i_1 + i_2) = 0$

$10i_1 + 14i_2 = 10$ ...(ii)

Equation (i) × (10) – Equation (ii) × 17

$170i1 + 100i2 = 200$

$-170i_1 + 238i_2 = 170$

$-138i_2 = 30$

$i_2 = -\frac{30}{138} = -0.217A$

"–ve" sign indicates that current flows from "+ve" to "–ve" terminal in 10 V battery.

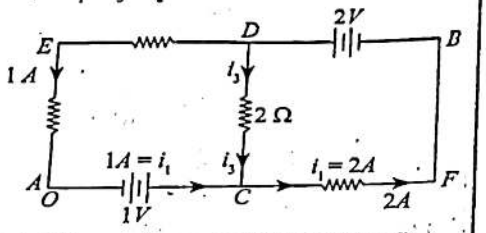
134. (a) $\varepsilon - i_1R - i_1R = 0$

$8 - 4i_1 - 4i_1 = 0,\ i_1 = 1A$

135. (a) Let the potential at $A = V_A = 0$

Now at junction C, according to KCL, net current flow at point C is zero.

$i_1 + i_3 = i_2 \Rightarrow i3 = i2 - i1 = 2 - 1 = 1\,A$

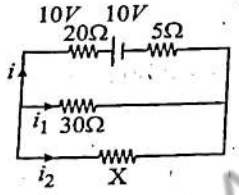


Now analyse potential along ACDB;

$V_A + 1 + i_3(2) - 2 = V_B$

$0 + 1 + 2(1) - 2 = V_B,\ V_B = 3 - 2 = 1V$

136. [30]



$V_1 = \varepsilon_1 - i.r_1$

$0 = 10 - i \times 20 \Rightarrow i = 0.5\,A$

$V_2 = \varepsilon_2 - ir_2$

$= 10 - 0.5 \times 5 \Rightarrow V_2 = 7.5\,V$

$0.5 = \frac{7.5}{30} + \frac{7.5}{x}$

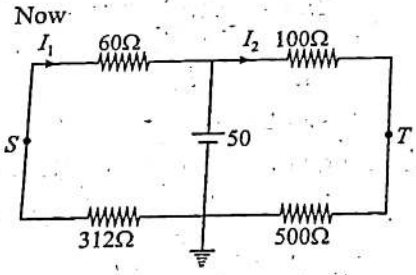
$0.5 = 0.25 + \frac{7.5}{x}$

$\frac{7.5}{x} = 0,25;\ x = \frac{7.5}{0.25} = 30$

137. [0.26 to 0.28]

$R_3' = 300(1 + \alpha\Delta T) = 312\,\Omega$

Now



$I_1 = \frac{50}{372}$ and $I_2 = \frac{50}{600}$

$V_S - V_T = 312\,I_1 - 500\,I_2$

$= 41.94 - 41.67 = -0.27\,V$

138. (c) For null point, $\frac{4.5}{60} = \frac{R}{40}$

As Resistance, $R = \frac{\rho\ell}{A} = \frac{\rho\ell}{\pi r^2}$

$4.5 \times 40 = \rho \times \frac{0.1}{\pi \times 7 \times 10^{-4}} \times 60$

$\Rightarrow \rho = 66 \times 10^{-7}\,\Omega \times m$

139. (d) As dimension of wire does not effect specific resistance so, it will not change.

140. (d) According to Kirchoff voltage is low

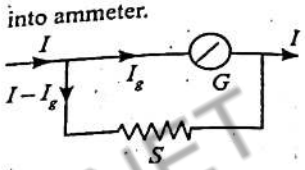
$V_1 + V_2 - V_3 = 0 \Rightarrow V_1 + V_2 = V_3$

141. (c) Given $G = 10\,\Omega$

$I_g = 3$ mA

$I = 8A$

In case of conversion of galvanometer into ammeter.



We have $I_g G = (I - I_g)S$

$S = \frac{I_g G}{I - I_g}$

$S = \frac{(3 \times 10^{-3})10}{8 - 0.003} = 3.75 \times 10^{-3}\,\Omega$

142. (c) Since all the resistance in series,

Hence, $R_{eq} = 4000\,\Omega$

So current passing through circuit is,

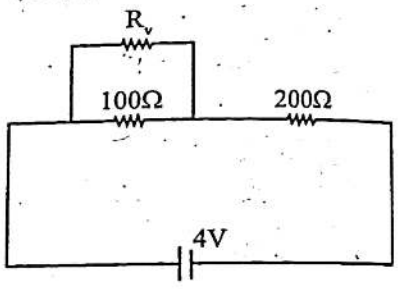
$i = \frac{4}{4000} = \frac{1}{1000}A$

Hence, $V_0 = i.R = \frac{1}{1000} \times 500 = 0.5\,V$

143. (200) Given $R_1 = 100$ ohm

$R_2 = 200$ ohm

$V = 4\,V$



$\frac{R_v 100}{R_v + 100} = \frac{200}{3}$

$3R_v = 2R_v + 200$

$R_v = 200$

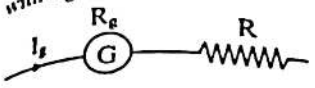
144. (c) $i = \frac{E_{eq}}{r_{eq}} = \frac{8 \times 5}{8 \times 0.2} = 25A$

As, $V = E - ir$

$= 5 - 0.2 \times 25 = 0$

@FAKE_CBSE_X @RAJ_EDUNET

145. (c) Let the resistor to be connected in series with R_G be R.

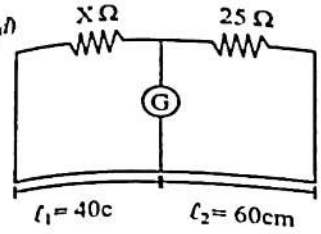


$$R = \frac{V}{I_g} - R_g = \frac{100}{5\times10^{-3}} - 50$$

$$= 20000 - 50$$

$$= 19950\Omega$$

146. (d)



Balance equation is given as,

$$\frac{25}{r\ell_1} = \frac{X}{r\ell_2} \quad (i)$$

$$\frac{25}{2r\ell_1'} = \frac{X}{2r\ell'} \quad (ii)$$

Solving (i) and (ii), we get

$\ell_2' = \ell_2 = 40$ cm

147. (*Bonus*) By using,

$I_s S = I_g G$

$$\Rightarrow \frac{95}{100} IS = \frac{5I}{100} G$$

$$\Rightarrow S = \frac{G}{19}$$

$$R_A = \frac{SG}{S+G} = \frac{\frac{G^2}{19}}{\frac{20G}{19}}$$

$$\therefore R_A = \frac{G}{20}$$

148. (c) For zero deflection $\frac{R}{3} = \frac{0.8}{1}$

$\Rightarrow R = 2.4$ mΩ

It is given that temperature fall in 10s = 20°C

$\Delta R = R\,\alpha\,\Delta t$

$$\alpha = \frac{\Delta R}{R\Delta t} = \frac{-0.6}{3\times20}$$

$= -10^{-2}C^{-1}$

149. (a) So, First case $\frac{2}{40} = \frac{X}{60} \Rightarrow X = 3$

In second case $X' = \boxed{\frac{2\times3}{2+3}} = 1.2\Omega$

$$\frac{2}{\ell} = \frac{1.2}{100-\ell}$$

$$200 - 2\ell = 1.2\ell$$

$$\ell = \frac{200}{3.2} = 62.5 \text{ cm}$$

$\therefore$ Shift in balance point = 22.5

150. (d) As $V = IR = E - Ir$

$\therefore I_1 \times 10 = \lambda \times 500 = \varepsilon - I_1$

[Let potential gradient be λ.]

$\Rightarrow 500\lambda = \varepsilon - 50\lambda r_1$ ...(1)

Also, $I_2 \times 1 = \lambda \times 400 = \varepsilon - I_2$

$\Rightarrow 400\lambda = \varepsilon - 400\lambda r_2$ ...(2)

From eq^n (1) & eq^n (2)

$$\therefore 100\lambda = 350\lambda r_1 \Rightarrow r_1 = \frac{10}{35} \approx 0.3\Omega$$

151. (c) The current in the galvanometer,

$$i_g = \frac{10}{400+100} = 20\times10^{-3}\,A$$

For ammeter

Let shunt resistance = r

$i_g R = (i - ig)r$

$20 \times 10^{-3} \times 100 = 10\,r$

$r = 20 \times 10^{-2}\,\Omega$

152. (2500)

The equivalent resistance

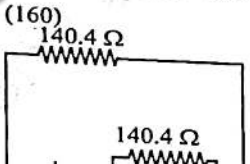
$$R_{eq} = \frac{10^4 R}{10^4 + R}$$

$V = 4V$, $I = 2mA$

$$I = \frac{V}{Req} \Rightarrow 2\times10^{-3} = \frac{4\left(10^4+R\right)}{10^4 R}$$

$\Rightarrow 20R = 40000 + 4R \Rightarrow R = 2500\Omega$

153. (160)



$$R_{eq.} = 140.4 + \frac{240\times10}{240+10}$$

$R_{eq.} = 150\,\Omega$

Reading of ammeter $= \frac{24}{150}$

$= 160$ mA

154. (b) Given:

$G = 200\,\Omega$ & $i_g = 20\,\mu A$

$$i = i_g\left(\frac{G}{S}+1\right)$$

$$\Rightarrow 20\times10^{-3} = 20\times10^{-6}\left(\frac{200}{S}+1\right)$$

$\Rightarrow S \approx 0.2\,\Omega$

155. (c) For voltmeter, Apply Kirchhoff's law $V - (I_g . G)$

$-I_g . R = 0$

$$R = \frac{V}{I_g} - G$$

$$= \frac{50}{10^{-3}} - 54 = 49946$$

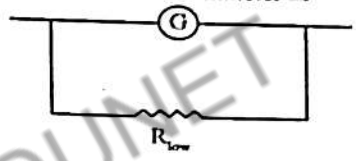
$= 49.946k\Omega \approx 50k\Omega$

For ammeter, $Ig . G - (I - Ig)r = 0$

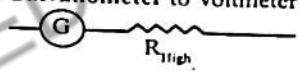
$$r = \frac{I_g G}{I - I_g} = \frac{10^{-3}\times54}{(10-1)\times10^{-3}} = 6\Omega$$

156. (a) Error of voltmeter decreases with increase in its resistance.

157. (c) Galvanometer to Ammeter $\Rightarrow$



Galvanometer to Voltmeter $\Rightarrow$



158. [30]

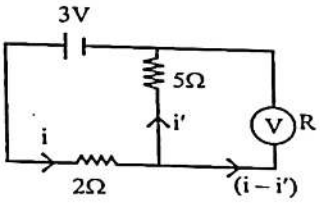
$$\frac{R_1+R_2}{10} = \frac{60}{40} \Rightarrow R1 + R2 = 15$$

Now $\frac{R_1R_2}{(R_1+R_2)\times3} = \frac{40}{60}$

$\Rightarrow R_1R_2 = 30\Omega2$

159. [20]

$$i' = \frac{2V}{5\Omega} = \frac{2}{5}A$$



$$i = \frac{(3-2)}{2} = \frac{1}{2}A$$

$\therefore$ Current through voltmeter

$$= \frac{1}{2} - \frac{2}{5} = \frac{1}{10}A$$

$\therefore$ For voltmeter $V = (i - i')R$

$$2 = \left(\frac{1}{10}\right)R \Rightarrow R = 20\Omega$$

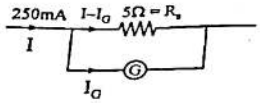
160. [50]

Given, $I = 250$ mA $= 0.250$ A

$R_s = 5\Omega$

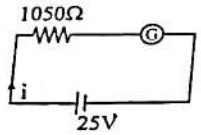
$G = ?$

@FAKE_CBSE_X @RAJ_EDUNET



$(I-IG)R_s = IG\,.\,G$

$\Rightarrow I_G = \frac{IRs}{Rs+G} = \frac{0.250\times 5}{5+G}$ ....(i)



$I_G = \frac{25}{1050+G}$ ...(ii)

From (i) and (ii)

$\frac{0.250\times 5}{5+G} = \frac{25}{1050+G}$

$G = 50\Omega$

161. [2] For a balanced meter – bridge,

$\frac{R}{S} = \frac{l}{100-l}$

$\Rightarrow \frac{2}{\left(\frac{3X}{3+X}\right)} = \frac{40+22.5}{60-22.5} = \frac{5}{3}$

$\Rightarrow \frac{6}{5} = \frac{3X}{3+X}$

$\Rightarrow x = 2$

162. [5] When the external resistance, R = 5Ω

$\frac{\varepsilon}{r+5}\times 5 = 200x$ ...(i)

When the external resistance, R = 15Ω

$\frac{\varepsilon\times 15}{r+15} = 300x$ ...(ii)

Dividing eqn (i) by (ii)

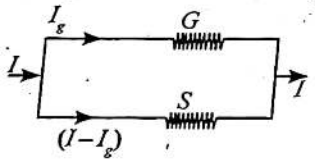
$\Rightarrow r = 5\Omega$

163. (b) Given, $G = 72\Omega$, $S = 8\Omega$

$\Rightarrow Ig\,G = (I-Ig)S$

$\Rightarrow \frac{I-I_g}{I_g} = \frac{G}{S}$

$\Rightarrow \frac{I}{I_g} - 1 = \frac{72}{8}$



$\Rightarrow \frac{I}{I_g} = 10$

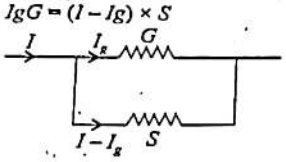
$\Rightarrow \frac{I_g}{I} = \frac{1}{10}$

$\Rightarrow \frac{I_g}{I}\times 100 = 10\%$

% of *current* which passes through galvanometer is 10%.

164. (b) In galvanometer

$IgG = (I-Ig)\times S$



$\frac{I_g}{I} = \frac{S}{S+G} \Rightarrow \frac{1}{3} = \frac{S}{S+G} \Rightarrow G = 2S$

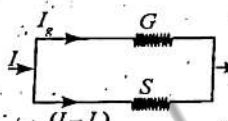
165. (b) Given, $G = 72\Omega$, $S = 8\Omega$

$\Rightarrow Ig\,G = (I-Ig)S$

$\Rightarrow \frac{I-I_g}{I_g} = \frac{G}{S}$

$\Rightarrow \frac{I}{I_g} - 1 = \frac{72}{8}$

$\Rightarrow \frac{I}{I_g} = 10$



$\Rightarrow \frac{I_g}{I} = \frac{1}{10}$

$\Rightarrow \frac{I_g}{I}\times 100 = 10\%$

% of *current* which passes through galvanometer is 10%.

166. (d)

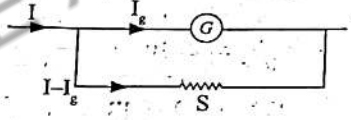


Figure of merit $\frac{I_g}{\theta} = K$

$I_g = Kn$

$I = \frac{I_g}{s}(G+S)$

$\therefore I = \frac{nK}{S}(G+S)$

167. [2400] $\frac{S}{R} = \frac{l}{100-l} \Rightarrow S = 5.6\times\frac{30}{100-30}$

$\Rightarrow S = \frac{3}{7}\times 5.6k\Omega = 3\times 0.8k\Omega$

$= 2.4k\Omega = 2400\Omega$

168. [19]

Unknown resistance R

Known resistance, $P = 15\Omega$

At null point

$\frac{P}{R} = \frac{l}{100-l}$, $\frac{15}{R} = \frac{43+2}{100-(43)}$

$R = 19\Omega$

169. [40]

Since, potential gradient is independent of area therefore, balancing point will be same .i.e.

$x = 40$ cm

170. [10]

Using the balance condition of Wheatstone bridge:

$\frac{R}{3} = \frac{4}{6} \Rightarrow R = 2\Omega$

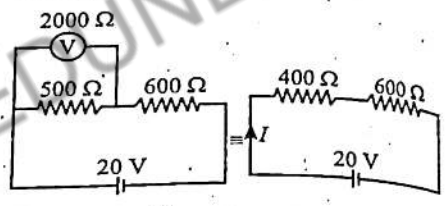
Equivalent resistance of the circuit $R_{eq} =$

$\frac{9\times 6}{9+6} = \frac{54}{15}\Omega$

From ohm's law,

$i = \frac{36}{\frac{54}{15}} = 10A$

171. [8]



$I = \frac{20}{400+600} = 20$ mA

Current through the voltmeter =

$I\times\frac{500}{2500} = 20\times\frac{500}{2500} = 4$ mA

∴ Voltage across the voltmeter = Current through in voltmeter × voltmeter resistance

$= 4\times 10{-}3\times 2000 = 8$ V

172. [20]

Initially, $\frac{P}{Q} = \frac{40}{60} = \frac{2}{3}$ ...(i)

$\frac{4}{Q} = \frac{2}{3} \Rightarrow Q = 6\Omega$

Finally, $\frac{P+x}{Q} = \frac{80}{20} = \frac{4}{1}$ ...(ii)

$\frac{4+x}{6} = \frac{4}{1}$

$x = 24-4 = 20\Omega\sigma$

173. [5]

$R_{AO} = \int_0^{1/2}\frac{\rho}{\pi}\frac{dx}{(r+4rx)^2} = \frac{2\rho}{3\pi r^2}$

$\therefore R_{OB} = \int_{1/2}^{1}\frac{\rho}{\pi}\frac{dx}{(r+4rx)^2} = \frac{2\rho}{15\pi r^2}$

$(x)\frac{2\rho}{15\pi r^2} = (1)\frac{2\rho}{3\pi r^2} \Rightarrow x = 5$

@FAKE_CBSE_X @RAJ_EDUNET

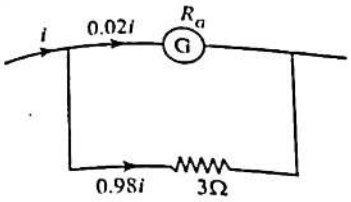
174. (a) Current at full deflection,

$$I_{max} = \frac{\text{Total number of division}}{\text{Sensitivity}}$$

$$= \frac{50}{2} = 25\text{mA}$$

$$R = \frac{V}{I_{max}} = \frac{50}{25} = 2\Omega$$

175. (d)



For Ammeter

$$I_G R_G = (1 - I_G)s$$

$$\frac{2i}{100} R_G = \frac{98i}{100} \times 5$$

$$R_G = 245\Omega$$

176. (c) Let, $V_A = 10\ V$, $VB = x\ V$, $V_c = 0\ V$, and $V_D = y\ V$

Net current from B is zero, so,

$$\frac{x-10}{100} + \frac{x-y}{15} + \frac{x-0}{10}$$

$$= 0 \Rightarrow 53x - 20y = 30 \quad \ldots (i)$$

Net current from D is zero, so,

$$\frac{y-10}{60} + \frac{y-x}{15} + \frac{y-0}{5}$$

$$= 0 \Rightarrow 17y - 4x = 10 \quad \ldots (ii)$$

Solving equations (i) and (ii), we get.

$x = 0.865$ and $y = 0.792$

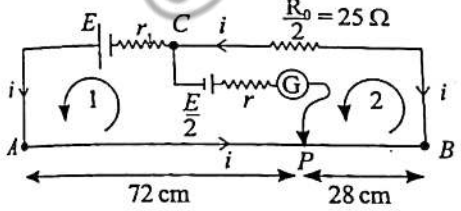
$$i_G = \frac{x-y}{15} = 4.87\ mA$$

177. [48]

Using the galvanometer coil balanced formula, under balanced condition,

$$\frac{12}{x} = \frac{6}{72-x} \Rightarrow x = \frac{144}{3}\ 48\text{ cm}$$

178. [3]



$$RAP = 72 \times \frac{50}{100} = 36\Omega$$

$$RPB = 28 \times \frac{50}{100} = 14\Omega$$

KVL Loop(1):

$$-i(14) - i(25) + \frac{\varepsilon}{2} = 0$$

$$i = \frac{\varepsilon}{78} \quad \ldots (i)$$

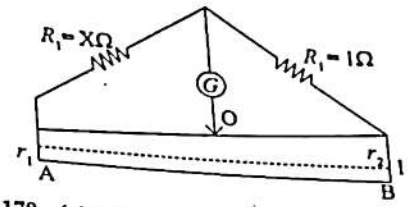
KVL loop (2).

$$-ir_1 + E - iR_{AB} - \frac{\varepsilon}{2} = 0$$

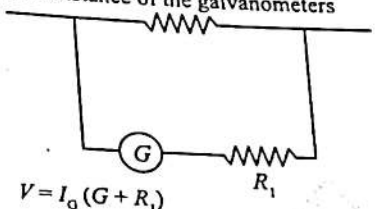
$$-\frac{\varepsilon}{78} r_1 + \varepsilon - \frac{\varepsilon}{78} \cdot 36 - \frac{\varepsilon}{2} = 0$$

$$\frac{r_1}{78} = \frac{3}{78}$$

$$r_1 = 3\Omega$$



179. (a) I_G is current in the galvanometers G is the resistance of the galvanometers



$$V = I_G (G + R_1)$$

$$1 = I_G (G + R_1)$$

$$2 = I_G (G + R_1 + R_2)$$

$$2 = 1 + I_G R_1$$

$$I_G R_2 = 1$$

$$R_2 = G + R_1$$

180. (c) For parallel combination of 10 kΩ and 400 Ω

$$R = \frac{40000}{104} = 384.61\Omega$$

The potential difference across 400 Ω is

$$V400\ \Omega = \frac{384.61}{384.61 + 800} \times 6 = 1.95\ V$$

181. (d) Current passing through the galvanometer

I = 6mA

Deflection in galvanometers, θ = 2°

Figure of Merit

$$= C = \frac{i}{q} = \frac{6' 10^{-3}}{2} = 3' 10^{-3}\ Am^2$$

182. (a) Voltage in the galvanometer,

$Vg = igRg = 10\text{–}3 \times 100$

$$= \frac{100}{1000} = \frac{1}{10}$$

Potential difference, $V = 10$ V

$$= R_g \left(\frac{V}{V_g} - 1 \right) = 100 \times 99 = 9.9\ \text{K}\Omega$$

183. [40] $\frac{X}{R} = \frac{75}{25} = 3$, $R = \frac{4\rho\ell}{\pi d^2}$

$$R' = \frac{4\rho\left(\frac{\ell}{2}\right)}{\pi\left(\frac{d}{2}\right)^2} = 2R$$

then $\frac{X}{R'} = \left(\frac{100-\ell}{\ell}\right)$

$$\frac{100-\ell}{\ell} = \frac{X}{2R} = \frac{3}{2}$$

$$\ell = 40.00\text{ cm}$$

184. [2] Current across 90Ω and 60Ω resistance

$$i_1 = \frac{40}{100} = \frac{2}{5}$$

Current across 90Ω and 110Ω resistance

$$i_2 = \frac{40}{200} = \frac{1}{5}$$

$$VA - VB = 40i_1 = 40 \times \frac{2}{5} = 16 \quad \ldots (i)$$

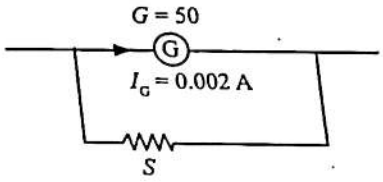
$$V_A - V_D = 90 I_2 = \frac{90}{5} = 18 \quad \ldots (ii)$$

From (i) and (ii) we get

$V_B - V_D = 18 - 16 = 2$ volt

Hence, potential difference across BD is 2 volt

185. (a) $S = \frac{50 \times 0.002}{(0.5 - 0.002)}$ $S = 0.2\Omega$



186. (b) G = 50Ω, S = 5000 Ω, $Ig = 4 \times 10\text{–}3$

Max. voltage, V = Ig(G + S)

V = 4 × 10–5 (50 + 5000) = 20.2 volt.

187. (c) Maximum current through galvanometer, I_{max}

$= 50 \times 20 \times 10^{-6} = 10^{-3}$ A

(i) $I_{max} = \frac{2}{100 + R_1} = 10^{-3} \Rightarrow R_1 = 1900\Omega$

(ii) $I_{max} = \frac{10}{R_G + R_1 + R_2}$

$$10^{-3} = \frac{10}{100 + 1900 + R_2} \Rightarrow R_2 = 8000\Omega$$

(iii) $I_{max} = \frac{20}{100 + 1900 + 8000 + R_3}$

$R_3 = 10000\Omega$

@FAIE_CBSE X @RAJ_EDUNET

188. (*a*) We know that, $x = \frac{R(100-l)}{l}$

for (1) $x = \frac{1000\times(100-60)}{60} \approx 667$

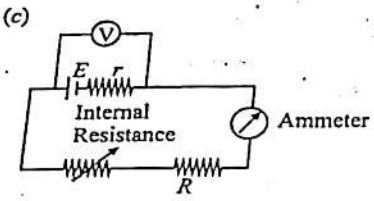
for (2) $x = \frac{100\times(100-13)}{13} \approx 669$

for (3) $x = \frac{10\times(100-1.5)}{1.5} \approx 656$

for (4) $x = \frac{1\times(100-1)}{1} \approx 99$

So reading in serial no. (4) is completely different hence correct answer (*a*).

189. (*c*)



$V = E - Ir$

When $V = V_0 = 0 \Rightarrow 0 = E - Ir$

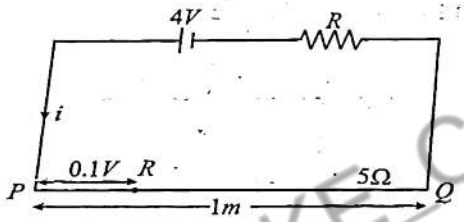
$\therefore E = Ir$

When $I = 0$, $V = E = 1.5$ V

$\therefore r = 1.5\ \Omega$

190. (c) Current, $i = \frac{4}{5+R}$

$V_{PQ} = i(5) = \frac{20}{5+R}$



$V_{PR} = \frac{V_{PQ}}{L}(0.1) = \frac{20}{5+R}\left(\frac{0.1}{1}\right) = \frac{2}{5+R}$

Now, $\frac{2}{5+R} = 5\times10^{-3}$

$2 = 25 \times 10{-}3 + 5 \times 10{-}3\ R$

$R = \frac{2-0.25}{5\times10^{-3}} = 395\ \Omega$

191. (*) According to ohm's law $V = IR$

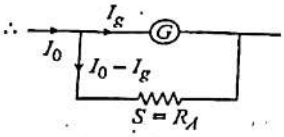
$\Rightarrow V = Ig = (R + G)$

$\Rightarrow 5 = 10{-}4 \times (2 \times 10^6 + x)$

$\Rightarrow x = -195 \times 10^4\ \Omega$ (Bonus)

192. (*b*) When galvanometer is used as an ammeter, shunt is used in parallel with galvanometer.

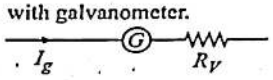
$\therefore$



$\therefore I_g G = (I_0 - I_g) R_A$

$\therefore R_A = \left(\frac{I_g}{I_0 - I_g}\right) G$

When galvanometer is used as a voltmeter, resistance is used in series with galvanometer.



$I_g(G + R_V) = V = GI_0$ (given $V = GI_0$)

$\therefore R_V = \frac{(I_0 - I_g)G}{I_g}$

$\therefore R_A R_V = G^2$ and $\frac{R_A}{R_V} = \left(\frac{I_g}{I_0 - I_g}\right)^2$

193. (*c*) $\frac{R_1}{R_2} = \frac{2}{3}$ ...(*i*)

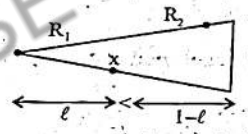
and $\frac{R_1 + 10}{R_2} = 1$ ...(*ii*)

After solving (*i*) and (*ii*)

$R2 = 30\Omega$ and $R1 = 20\Omega$

Now, $R1 = \frac{30\times R}{30+R} = 20 \Rightarrow R = 60\Omega$

194. (*c*) $\frac{R'}{R_1} = \frac{R'}{R_2} \Rightarrow R_1 = R_2 = \frac{R}{2}$



Total resistance = R

$= \int_{\text{wire}} dR = \int_0^1 \frac{k}{\sqrt{l}} \cdot d\ell = k\left[2\sqrt{\ell}\right]_0^1 = 2k$

$R_1 = \frac{R}{2} = k \Rightarrow \int_0^{Q} \frac{k}{\sqrt{\ell}} \cdot d\ell = k$

$[2k\sqrt{\ell}]_0^{\ell} = k$, $\sqrt{\ell} = \frac{1}{2}$, $l = 0.25$ m

195. (*b*) $i_{g_0} = 4\times10^{-4}\times25 = 10^{-2}$ A

$V_o = i_{g_o}(R_G + R)$

$\therefore R_g + R = \frac{V_o}{i_{g_o}} = \frac{2.5}{10^{-2}} = 2.5\times10^2 = 250$

$\Rightarrow R = 250 - 50 = 200\ \Omega$

196. (*d*) Let the length AJ, be *x* when galvanometer shows no deflection

$V_{AJ} = IR_{AJ}\frac{E}{3} = \left(\frac{E}{12r+3r}\right)\times\left(\frac{x}{L}\times12r\right)$

$x = \frac{15r\times L}{12r\times3} = \frac{5}{12}L$

197. (*c*) $Rg = 20\Omega$

Division on both side = 30

$FOM = \frac{1}{\phi} = 0.005$ A/Div.

Current sensitivity = $\frac{1}{FOM} = 0.005$ Div/A

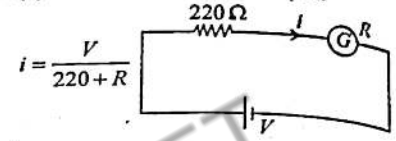
Maximum current = $0.005 \times 30 = 0.15$

$V = Ig(\text{max})(20 + R)$

$15 = 0.15[20 + R]$, $100 = 20 + R$

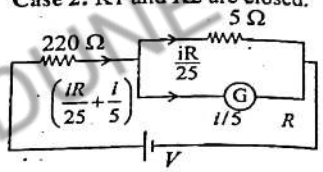
$\Rightarrow R = 80\Omega$

198. (b) **Case 1:** K1 and K2 are open.



$i = \frac{V}{220+R}$

Case 2: K1 and K2 are closed.



$\left(\frac{iR}{25} + \frac{i}{5}\right)220 + \frac{i}{5}R = V$

$\left(\frac{iR}{25} + \frac{i}{5}\right)220 + \frac{i}{5}R = i(220+R)$

After solving R = 22 W

199. (*d*) We know that, $\frac{P}{Q} = \frac{R}{S}$

Case 1: $\frac{P}{Q} = \frac{400}{x}$, **Case 2:** $\frac{Q}{P} = \frac{405}{x}$

Using case 1 and case 2:

$x2 = 400 \times 405$, $x = 402.5\ \Omega$

200. (b) When $Rh = 2\ \Omega$

$i_1 = \frac{6}{4+2} = 1$A

$E_1 = \frac{1\times4}{AB}\times AJ \Rightarrow AJ = \frac{AB}{4}E_1$

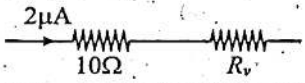
When $Rh = 6\ \Omega$

$i_2 = \frac{6}{4+6} = 0.6$A

$E_2 = \frac{0.6\times4}{AB}\times AJ \Rightarrow AJ = \frac{AB}{2.4}E_2$

$\therefore E2 = 0.6 \times E1 = 0.6 \times 0.5 = 0.3$ V

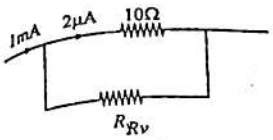
201. (*a,c*)



$202....1 = 2 \times 10^{-6}(10 + R_v)$

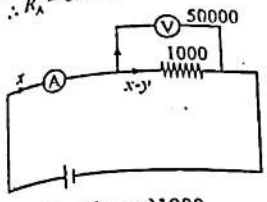
$\therefore R_v = 49990\ \Omega$

@FAKE_CBSE_X@RAJ_EDUNET



$2\times10^{-6}\times10=10^{-3}R_A$

$\therefore R_A=0.02\,\Omega$



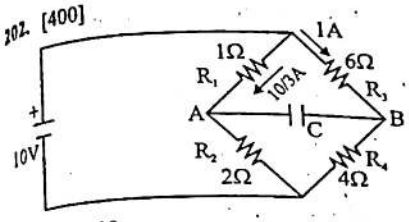
$50000y=(x-y)1000$

$\therefore 51y=x$

$\text{Reading}=\dfrac{50000y}{x}=980$

RC Circuit

202. [400]



$V_A+\dfrac{10}{3}(1)-6(1)=V_B$

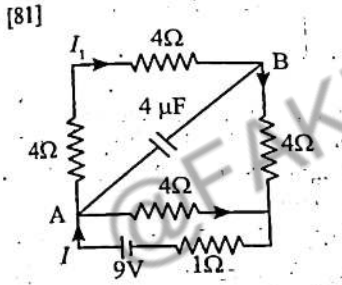
$\Rightarrow V_A-V_B=6-\dfrac{10}{3}=\dfrac{8}{3}$ volt

Accumulated charge on C (Q)

$=C(V_A-V_B)$

$=150\times\dfrac{8}{3}=400\mu C$

203. [81]



$I=\dfrac{V}{R_{eq}}I=\dfrac{V}{R_{eq}}=\dfrac{9}{1+\dfrac{12\times4}{12+4}}=\dfrac{9}{4}$

$I_1=\dfrac{9}{4}\times\dfrac{4}{16}=\dfrac{9}{16}$

$V_A-V_B-V_1\times8=\dfrac{9}{16}\times8=\dfrac{9}{2}$ V

The energy stored by the capacitor will be

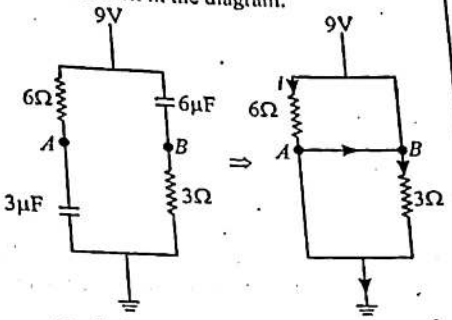
$\therefore U=\dfrac{1}{2}\times4\times\dfrac{81}{4}\mu J$

$\therefore U=\dfrac{81}{2}\mu J$

$\therefore x=81$

204. [36]

At steady state, capacitor behaves as an open circuit and current flows in circuit as shown in the diagram.



Equivalent resistance,

$R_{eq}=9\,\Omega$

$i=\dfrac{9V}{9W}=1A$

$\Delta V_{6\Omega}=1\times6=6V$

$V_A=3V$

So, potential difference across 6μF is 6V.

The charge stored in 6(mu)F capacitor,

Hence, $Q=C\Delta V$

$=6\times6\times10^{-6}\,C=36\,\mu C$

205. (*d*) In steady state

Req = 12Ω

$I=\dfrac{6}{12}=0.5A$

Now, $q_1=C_1V_1=12\,\mu C$

$q_2=C_2V_2=24\,\mu C$

$\therefore\dfrac{q_1}{q_2}=\dfrac{1}{2}$

206. [60] No voltage drop across $R_2=5\Omega$, because in steady state there will be no current in branch of capacitor

$\Rightarrow I_2=0$

$I_1=I_3=\dfrac{10}{4+6}=1A$

$V_{R_3}=V_c+V_{R_2}\ \&\ V_{R_2}=0$

$I_3R_3=V_c$

$V_c=1\times6=6$ volt

$q_c=CV_c=10\times6=60\,\mu C$

207. [4] Let initial electric field between plates be E_0,

$E=\dfrac{E_0}{3}\Rightarrow V=\dfrac{V_0}{3}$

$\dfrac{V_0}{3}=V_0e^{-\frac{t}{\tau}}$

$t=\tau\ell n3$

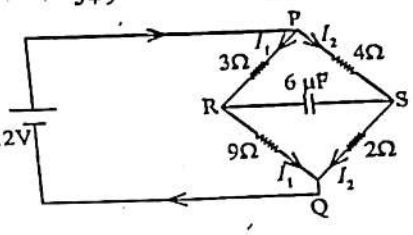
$6.6\times10^{-6}=R(1.5\times10^{-6})(1.1)$

$R=\dfrac{6}{1.5}=4\Omega$

208. [75]

From ohm's law

$I_1=\dfrac{12}{3+9}=1A$ and $I_2=\dfrac{12}{4+2}=2A$



$V_P-V_R=3I_1=3V$ ... (*i*)

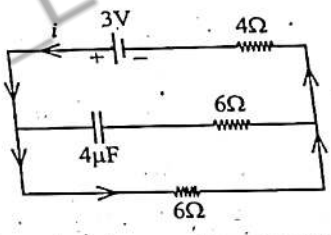
$V_P-V_S=2\times4=8V$ ... (*ii*)

Subtracting eq. (*i*) from eq. (*ii*)

$V_R-V_S=5V\Rightarrow V=5V$

$U=\dfrac{1}{2}CV^2=\dfrac{1}{2}\times6\times5^2=75\mu J$

209. (*a*)



In steady state, current do not pass through capacitor, therefore $I=\dfrac{3}{6+4}=\dfrac{3}{10}$

Potential difference on 6Ω resistance

$V=6\times\dfrac{3}{10}=1.8$ volt

Capacitor will have same potential difference there fore, charge on it $q=CV$

$=(4\,\mu F)\cdot(1.8\text{ volt})=7.2\,\mu C.$

210. (b) At steady state, capacitors are open.

$\therefore i=\dfrac{4V}{6+2+8}=\dfrac{1}{4}A$

Voltage across C_1 is

$V_1=V_{AC}=i(6\Omega+2\Omega)=8i$ Volt

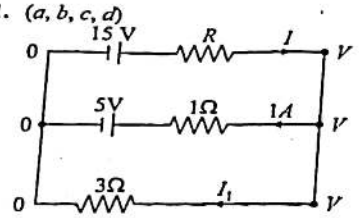
Voltage across C_2 is

$V_2=V_{BD}=i(2\Omega+8\Omega)=10i$ Volt

$\Rightarrow\dfrac{V_1}{V_2}=\dfrac{8i}{10i}=\dfrac{4}{5}$

@FAKE_CBSE_X @RAJ_EDUNET

211. *(a, b, c, d)*



Voltage drop across 1Ω be *V*, then

$0 + 5 + 1 \times 1 = V,\ V = 6$

Voltage drop across R = Voltage drop across 1.

$0 + 15 - I \times R = 6$

$IR = 9$ ...(*i*)

$\Rightarrow$ Voltage drop across 3Ω = Voltage drop across 1Ω, $3I_1 = 6, I_1 = 2A$

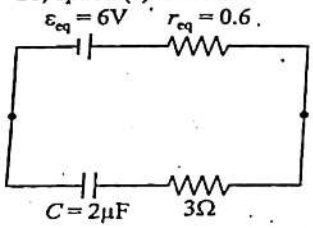
So, option (b) is correct

From Kirchoff's current loop law,

$\Rightarrow I = 1 + 2, I = 3$

From eq^n(*i*), $R = 3\Omega$

So, option (a) is correct.



$$\frac{1}{r_{eq}} = \frac{1}{3} + 1 + \frac{1}{3} \Rightarrow r_{eq} = 0.6\Omega$$

$$\varepsilon_{eq} = \frac{\frac{15}{3} + \frac{5}{1} + \frac{0}{3}}{\frac{1}{3} + \frac{1}{1} + \frac{1}{3}} = 10 \times \frac{3}{5} = 6V$$

$q_{max} = C\varepsilon_{eq} = 2 \times 6 = 12\ \mu C$

Time constant, $\tau = RC = (3 + 0.6) \times 2 = 7.2\ \mu s$

$$\therefore i = \frac{6}{3 + 0.6} e^{-\frac{t}{\tau}} = \frac{5}{3} e^{-\frac{7.2}{7.2}} = \frac{5}{3} e^{-1} \approx 0.6A$$

212. *(d)* $q = q_0 e^{-t/Rc}$ (discharging eq. of capacitor)

$$t \to \frac{t}{2} \Rightarrow q \to \frac{q_0}{\sqrt{2}}$$

$$\frac{q_0}{\sqrt{2}} = q_0 e^{-t_1/\tau}$$

$$\sqrt{2} = e^{-t_1/\tau} \Rightarrow t_1 = \tau \ell n \sqrt{2}$$

$$\frac{q_0}{8} = q_0 e^{-t_2/Rc}$$

$$8 = e^{t_2/Rc} \Rightarrow t_2 = \tau \ell n\, 8$$

$$\frac{t_1}{t_2} = \frac{\ln \sqrt{2}}{\ln 8} = \frac{\frac{1}{2} \ln 2}{3 \ln 2} = \frac{1}{6}$$

213. [10]

$q = CV$

$$= \left(\frac{11}{10} \times 10^{-6}\right)\left(\frac{100}{11}\right)$$

$= 10\ \mu C$

214. *(b)* $V = V0(1 - e^{-t/RC})$

$V = 10(1 - e^{-t/RC})$

$2 = 20(1 - e^{-t/RC})$

$$\frac{1}{10} = 1 - e^{-t/RC}$$

$$e^{t/RC} = \frac{10}{9}$$

$$\frac{t}{RC} = \ln\left(\frac{10}{9}\right) = 0.105$$

$$C = \frac{10^{-6}}{10 \times 0.105} = 0.95\mu F$$

215. [100]

We know that, charge on the capacitor, $Q = CV$

$Q = 50\ \mu F \times 2V = 100 \times 10{-}6C$

$Q = 100\ \mu C$

Hence, charge on the upper plate of capacitor is 100 μC

216. (d) Given, $C = 1\ \mu F = 1 \times 10{-}6\ F$

$V0 = 100$ volt, V = 50 volt

$R = 100\ \Omega$

Where $\tau = RC = 100 \times 10^{-6}$ sec

$$50V = 100V\left(1 - e^{\frac{-t}{10^{-4}}}\right)$$

$$\frac{1}{2} = 1 - e^{-10^4 t} \Rightarrow \frac{1}{2} = e^{-10^4 t}$$

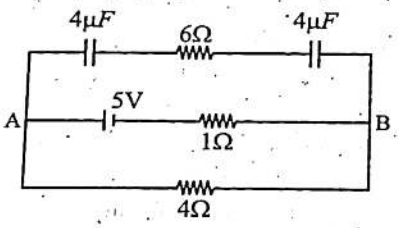
$2 = e + 104t \Rightarrow \ell n2 = 104t$

$$t = \frac{\ell n 2}{10^4}$$

$t = 0.693 \times 10^{-4}$ sec.

217. *(d)* $V_{AB} = \frac{5}{5} \times 4 = 4V$

$\Rightarrow Q = Ceq\ V = 2 \times 4 = 8\mu c$ [$\because Ceq = 2 + 2 = 4\mu F$]



218. [2] $I = \frac{V}{R} = \frac{30/3}{5 \times 10^6} = 2 \times 10^{-6}$

219. [1.33] After long time we can replace the capacitor by open circuit.

i current in circuit = 1/3 ampere

$v_{AB} = 2 - 2\left(\frac{1}{3}\right) = \frac{4}{3}$ volt

Potential drop across capacitor

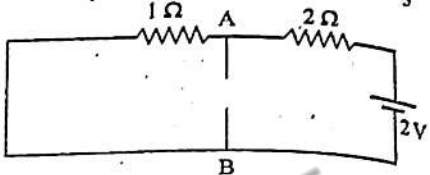
$\Delta V = \frac{4}{3}$ volt

$\therefore$ Charge on capacitor, $q_1 = C\Delta V$

$= 1 \times \frac{4}{3}\mu C$

$q_1 = 1.33\mu C$

220. [0.67] After long time I in circuit = $\frac{2}{3}$ ampere



$V_A - V_B = i_2 \times 1 = \frac{2}{3}$V

Potential difference across capacitor

$\Delta V = \frac{2}{3}$ volt

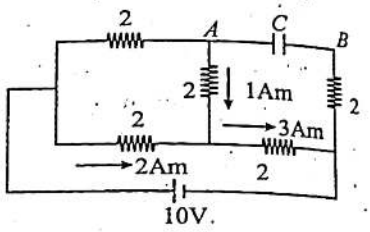
Charge on capacitor $q_2 = C\Delta V$

$= 1 \times \frac{2}{3} = 0.67\mu C$

221. *(a)* $\tau = RC = 10\ \mu s$

For $0 < t < 5\ \mu s$, it will get charged. For $5 < t < 10\ \mu s$ potential is constant and again gets charged after that.

222. [8]



After solving the circuit we got the final current distribution as shown in the above diagram. So potential difference between A and B is

0 + (2 × 3) + (2 × 1) = 8 volt

223. [6] After connection is common potential

$$V_{common} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$

$$= \frac{60 \times 20 + 0}{120} = 10V$$

Energy loss =

$$U_i - U_f = \frac{1}{2}CV^2 - \frac{1}{2}(2C) \times V^2_{Common}$$

$$= \frac{1}{2} \times 60 \times 10^{-12} \times (20)^2$$

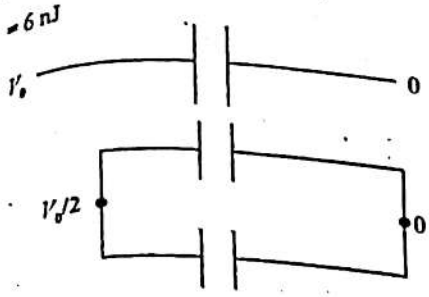
$$-60 \times 10^{-12} \times (10)^2$$

@FAKE_CBSE_X @RAJ_EDUNET

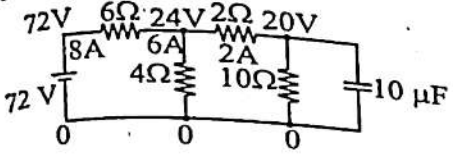
$= 60 \times 10^{-12} (200 - 100)$

$= 6000 \times 10^{-12}$

$= 6\ nJ$



4. (*a*) Different potential is shown at different points.



VC = 20 V, C = 10 μF

1. (*c*) Given, $I = 5A$,

$\rho = 1.7 \times 10^{-8}\ \Omega$-m,

$r = 5\ mm = 5 \times 10^{-3}$ m,

$v_d = 1.1 \times 10^{-3}$ m/s

Mobility of charges in a conductor is given by

$$\mu = \frac{v_d}{E} \qquad ...(i)$$

and resistivity is given by

$$\rho = \frac{E}{J} = \frac{E}{I/A} \quad (\because J = \sigma E = \frac{1}{\rho} \times E)$$

$$\Rightarrow \rho = \frac{EA}{I}$$

or $$E = \frac{\rho I}{A} \qquad ...(ii)$$

From Eqs. (*i*) and (*ii*), we get

$$\mu = \frac{v_d A}{\rho I}$$

Substituting the given values, we get

$$\mu = \frac{1.1 \times 10^{-3} \times \pi \times (5 \times 10^{-3})^2}{1.7 \times 10^{-8} \times 5}$$

$$= \frac{86.35 \times 10^{-9}}{8.5 \times 10^{-8}} = 10.1 \times 10^{-1}$$

$$\Rightarrow \mu = 1\ m^2/V.s$$

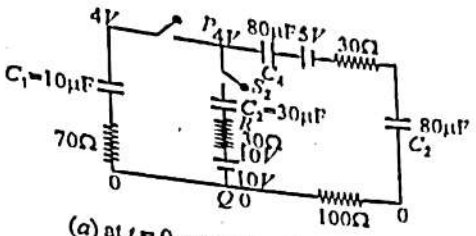
2. (*c*) Relation between resistance and resistivity is $R = \rho \frac{l}{a}$

Therefore, $R = \rho \frac{l}{l \times t} = \frac{\rho}{t}$

$\therefore q = CV = 10 \times 10\text{-}6 \times 20$

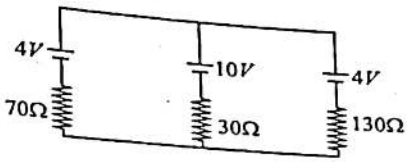
$q = 200\ \mu C$

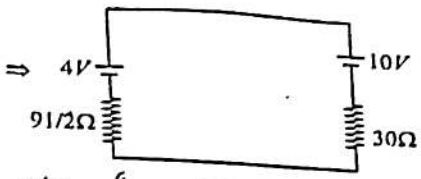
225. (*c,d*)



(*a*) at $t = 0$, capacitor C_1 acts as a battery of 4V, C_4 and C_3 of $\frac{1}{2}$ V each, C_2 is shorted

Circuit is





$$\Rightarrow I = \frac{6}{30 + \frac{91}{2}} = 0.079A$$

(*b*) and (*d*)

At steady state, When capacitor is fully charged it behave as open circuit and current through it zero.

Hence, charge on each capacitor is same.

$Q = C_{eq} V = (8\ \mu F) \times 5$, $Q = 40\ \mu C$

Now, $V_p - \frac{40}{10} = V_Q$, $V_p - V_Q = 4V$

(*c*) At $t = 0$, S_1 is closed, capacitor act as short circuit.

$$i = \frac{V}{R_{eq}} = \frac{5}{200} = 25mA$$

JEE-Advanced

3. (*d*) When a steady current flows in a metallic conductor of non-uniform cross section then the drift speed is $V_d = (I / neA)$ and the electric field $E = I/\sigma A$

$\Rightarrow V_d \propto 1/A \Rightarrow E \propto 1/A$

$\Rightarrow$ Only the current remains constant.

In a metallic conductor of non-uniform cross-section, only the current remains constant along the entire length of the conductor.

4. (*d*) A conductor's resistance is directly proportional to temperature, whereas a semiconductor's resistance is inversely proportional to temperature.

As Germanium is a semiconductor & copper is a conductor.

When copper is cooled, its resistance decreases while Germanium's resistance increases.

Hence, resistance of copper decreases, and resistance of germanium increases.

5. [False] Even when there is no potential difference applied across the conductor, electrons move randomly within it.

Because the motion is so random, the net effect on electrical conduction is zero because the motion is random and opposite, so it is neutralized.

The average velocity of electrons is zero.

6. (*a*) The combination of resistances is shown in figure.

$$R_{PQ} = \frac{R\left(\frac{R}{3} + \frac{R}{2}\right)}{R + \frac{R}{3} + \frac{R}{2}} = \frac{\frac{5R^2}{6}}{\frac{11R}{6}} = \frac{5R}{11}$$

$$R_{QR} = \frac{\frac{R}{2}\left(R + \frac{R}{3}\right)}{\frac{11R}{6}} = \frac{\frac{2R^2}{3}}{\frac{11R}{6}} = \frac{4R}{11}$$

$$R_{PR} = \frac{\frac{R}{3}\left(R + \frac{R}{2}\right)}{\frac{11R}{6}} = \frac{\frac{R^2}{2}}{\frac{11R}{6}} = \frac{3R}{11}$$

Maximum resistance will be between P and Q.

Hence, the maximum value lies between P and Q.

7. (*a*) The circuit is symmetrical about axis POQ. Therefore the equivalent circuit is drawn

$$\therefore \frac{1}{R_{PQ}} = \frac{1}{4R} + \frac{1}{4R} + \frac{1}{2r}$$

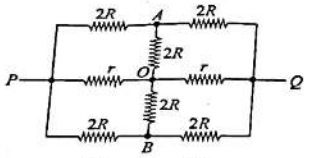
$$= \frac{1}{2R} + \frac{1}{2r} = \frac{R + r}{2Rr}$$

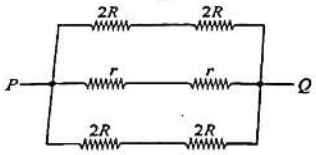
$$\Rightarrow R_{PQ} = \frac{2Rr}{R + r}$$

If a potential difference is applied across P and Q, there will be no currents in arms AO and OB.

So these resistance will be ineffective.

@FAKE_CBSE_KOTA_EDUNET





8. [4] In series, $i=\frac{2E}{2+R} \Rightarrow J_1 = i^2R$

$$J_1 = \left(\frac{2E}{2+R}\right)^2 \cdot R$$

In parallel, $i=\frac{E}{0.5+R}$

$$\therefore\ J_2 = i^2R = \left(\frac{E}{0.5+R}\right)^2 .R$$

$$\frac{J_1}{J_2} = 2.25$$

Solving we get, $R = 4\Omega$

9. [2] The circuit diagram is given labels as given in the diagram below.

The resistances AP and PQ are in series, therefore, their equivalent resistance $R_1 = 3 + 3 = 6$ ohms.

Now, equivalent resistance $R_1 = 6$ ohms and resistance 6 ohms between AQ are in parallel.

The equivalent resistance of circuit APQ is $\frac{1}{R_1}=\frac{1}{6}+\frac{1}{6} \Rightarrow R_1 = 3$ ohms.

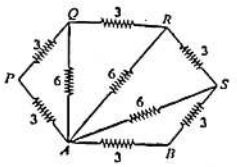
Similarly, resistance R_3 between A and R is $\frac{1}{R_3}=\frac{1}{6}+\frac{1}{6} \Rightarrow R_3 = 3$ ohms and the resistance R_4 between A and S is given as $R_4 = 3$ ohms.

The equivalent resistance between A and S, R_4 and the resistance between B and S are in series, therefore, their equivalent resistance $= 3 + 3 = 6$ ohms.

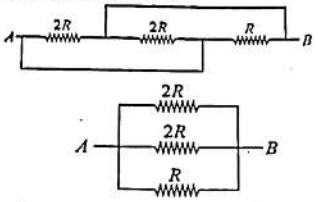
Therefore, effective resistance between A and B is given as

$$\frac{1}{R_{AB}}=\frac{1}{6}+\frac{1}{3} \Rightarrow R_{AB} = 2 \text{ ohms}$$

Hence, the effective resistance between points A and B is 2 ohms.



10. In this arrangement, all the resistors all connected in parallel.



$$\frac{1}{R_{AB}}=\frac{1}{R}+\frac{1}{2R}+\frac{1}{2R}$$

$$\Rightarrow \frac{1}{R_{AB}}=\frac{2}{R} \Rightarrow R_{AB}=\frac{R}{2}$$

11. The given circuit makes a balanced Wheatstone's bridge. The resistance between P and Q can be removed. All resistors have value R.

$\therefore\ R_{AB} = R$

12. (*d*) $R=\frac{V^2}{P}$ or $R \propto \frac{1}{P}$

$$\Rightarrow \frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$$

13. (*c*) Applying, $P=\frac{V^2}{R}$, $R_1 = 1\Omega$, $R_2 = 0.5\Omega$ and $R_3 = 2\Omega$

$V_1 = V_2 = V_3 = 3V$

$$\therefore\ P_1=\frac{(3)^2}{1}=9W$$

$$P_2=\frac{(3)^2}{0.5}=18W$$

and $P_3=\frac{(3)^2}{2}=4.5W$

$\therefore\ P_2 > P_1 > P_3$

14. (*a*) Here, the correct answer is heat produced in bar BC is 4 times the heat produced in bar AB, because current flowing through the bars is equal.

Heat produced

$H = I^2Rt$

$H \propto R$

$$\frac{H_{AB}}{H_{BC}}=\frac{R_{AB}}{R_{BC}}=\frac{\left(\frac{1}{2r}\right)^2}{\left(\frac{1}{r}\right)^2}$$

$$H_{BC} = 4H_{AB}$$

15. (*d*) $W = 0$. Therefore, from first law of thermodynamics,

$\Delta U = \Delta Q = I^2Rt = (1)^2\ (100)\ (5 \times 60)$

$= 30$ kJ.

16. (*a*) For case (*I*) $R_{net} = 3R$

For case (*II*) $R_{net} = 2/3\ (R)$

For case (*III*) $R_{net} = \frac{1}{\left(\frac{1}{R}+\frac{1}{R}+\frac{1}{R}\right)} = \frac{R}{3}$

For case (*IV*) $R_{net} = \frac{1}{\left(\frac{1}{R}+\frac{1}{R}\right)} + R = \frac{3R}{2}$

Power $= I^2R$

III < II < IV < I

17. (*d*) Using the power formula

$$\therefore\ R_1=\frac{V_1^2}{100}, R_2=\frac{V_2^2}{60}, R_3=\frac{V^2}{60}$$

$$W_1=\frac{V_1^2}{R_1}=\frac{V^2R_1}{(R_1+R_2)^2}$$

$$W_2=\frac{V_2^2}{R_2}=\frac{V^2R_2}{(R_1+R_2)^2}$$

and $W_3=\frac{V^2}{R_3}$

$$W_3 : W_2 : W_1$$

$$=\frac{(250)^2}{R_3}:\frac{(250)^2R_2}{(R_1+R_2)^2}:\frac{(250)^2}{(R_1+R_2)^2}R_1$$

or $W_3 : W_2 : W_1 = \frac{(250)^2}{V^2}\times 60 :$

$$\frac{(250)^2}{\left[\frac{1}{100}+\frac{1}{60}\right]^2 V^4}\times\frac{V^2}{60}:$$

$$\frac{(250)^2V^2}{\left[\frac{1}{100}+\frac{1}{60}\right]^2 V^4 \times 100}$$

$$W_3 : W_2 : W_1$$

$$= 60 : \frac{100\times100\times60\times60}{160\times160\times60} :$$

$$\frac{100\times100\times60\times60}{160\times160\times100}$$

$$= 64 : 25 : 15$$

$\therefore\ W_1 < W_2 < W_3$

18. (*b*) A wire of length L is linked in series with three identical cells with low internal resistances.

Let's say each cell's terminal potential difference is V and the wire, resistance is R.

The wire then produced heat in time t.

$$H=\left(\frac{(3V)^2}{R}\right)=ms\Delta T$$

@FAKE_CBSE_X @RAJ_EDUNET

where m is the mass of wire s is the specific heat of its material and ΔT is rise in its temperature.

When N identical cells are linked in series, the effective terminal potential is NV volts, and if the wire length, resistance, and mass are also doubled, the heat generated in the wire is

$$H = \left(\frac{(NV)^2}{2R}\right)t = 2ms\Delta T$$

$$\frac{N^2}{2\times 9} = 2 \Rightarrow N = 6$$

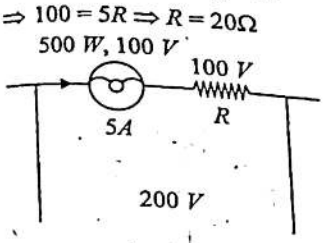
19. (*b*) Here, $P = VI \Rightarrow I = P/V = 500/100 = 5A$

This is the current through the bulb as well as the resistor R.

To consume 500 watts, the bulb must draw a current of 5 amps. Because the bulb and the resistance R are connected in series, the current in the resistance is now $5A$. There is a 100 V variation in resistance potential.

Voltage across R is $V_R = IR$

$\Rightarrow 100 = 5R \Rightarrow R = 20\Omega$



20. (*b*) $P_{4\Omega} = \left(\frac{i}{2}\right)^2 \times 4$

$P_{5\Omega} = i^2 \times 5 = 10$ cal/s

Then $i = \sqrt{2}$ amps

$$P_{4\Omega} = \left(\frac{1}{2}\right)^2 R = \left(\frac{1}{\sqrt{2}}\right)^2 \times 4 = 2 \text{ Cal/s}$$

21. (*c*) Given that,

Power rating of a heater, $P = 1000\ W$

Voltage rating of heater, $V = 100\ V$

Resistance of heater,

$$R = \frac{V^2}{P} = \frac{100\times 100}{1000} = 10\Omega$$

Given that, Power at which heater operates, $P' = 62.5\ W$

Hence, Voltage drop across the heater,

$V' = \sqrt{RP'} = \sqrt{10\times 62.5} = 25V$

Since the voltage drop across the heater is $25V$

Hence, voltage drop across 10Ω resistor is, $V_r = (100 - 25) = 75V$

Current in the circuit,

$$I = \frac{V_r}{R} = \frac{75}{10} = 7.5A$$

Further, the current divides into two parts.

Let I_1 be the current that passes through the heater.

$\therefore 25 = I_1 \times 10 \Rightarrow I_1 = 2.5\ A$

Hence, current through resistance R is, $I = 7.5 - 2.5 = 5A$

Applying Ohm's law across R, we get

$\therefore IR = 25 \Rightarrow R = \frac{25}{5} = 5\Omega$

22. (*a,b,c*) When both switches are open equivalent resistance in circuit 1

$$R_{C_1} = \frac{16}{11}\Omega$$

Equivalent resistance in circuit 2

$$R_{C_2} = \frac{6}{11}\Omega$$

For voltage source

$$P = \frac{V^2}{R}$$

$$P \propto \frac{1}{R}$$

$$R_{C_1} > R_{C_2}$$

$\Rightarrow P_2 > P_1$ (Option (*a*) correct)

For constant current source

$P = i^2R$

$P \propto R \Rightarrow P_1 > P_2$ (Option (*b*) correct)

When switch is closed

$$R'_{C_1} = \frac{5}{11}\Omega$$

$$R'_{C_2} = \frac{1}{2}\Omega$$

$R'_{C_1} < R'_{C_2}$

For voltage source

$P \propto \frac{1}{R} \Rightarrow Q_1 > P_1$ (Option (*c*) correct)

and $R'_{C_1} > R'_{C_2}$

For current source $P \propto R$

$Q_2 > Q_1$ (Option (*d*) is incorrect)

23. (*c, d*) The filament will become thinner as it nears the end of its life. Resistance will rise, resulting in less consumed power and hence less light. The temperature will not be distributed evenly. The filament will break at the maximum temperature point. As the black body radiation curve flattens out, the filament consumes less electrical power as the bulb nears its end of life.

24. (*b*) R_{Al} and R_{Fe} are parallel to each other.

$$R = \frac{pl}{A}$$

Al:

Area $= 7^2 - 2^2 = 45\ mm^2$

$\rho = 2.7 \times 10^{-8}\ \Omega m$

$l = 50\ mm$

Fe:

Area $= 2^2 = 4\ mm^2$

$\rho = 1.0 \times 10^{-7}\ \Omega m$

$l = 50\ mm$

Substituting values:

$R_{Al} = 30\ \mu\Omega$

$R_{Fe} = 1250\ \mu\Omega$

$$R_{total} = \frac{R_{Al}R_{Fe}}{R_{Al} + R_{Fe}} = \frac{30\times 1250}{30 + 1250}$$

$$= \frac{1875}{64}\mu\Omega$$

25. (*c*) The apparatus required to verify Ohm's law includes voltmeter, an ammeter, a test resistor and a variable battery. Voltmeter is made by connecting a high resistance with a galvanometer and is connected in parallel arrangement with the test resistor. Hence, an ammeter which is made by connecting a low resistance in parallel with galvanometer which is used to measure the current through test resistor.

26. (*a*) In a circuit ammeter is always connected in series and voltmeter is always connected in parallel. So the option (*a*) is the correct setups for verifying Ohm's law.

27. (*a*) Volume will remain same after stretching so, $V_{initial} = V_{final}$

$A_i l_i = A_f l_f$

$l_f = l_i + 0.001 \times l_i = 1.001\ l_i$

$$A_f = \frac{1}{1.001}A$$

$$R = \frac{\rho l}{A}$$

$$\frac{R_f}{R_i} = \frac{l_f \times A_i}{l_i \times A_f}$$

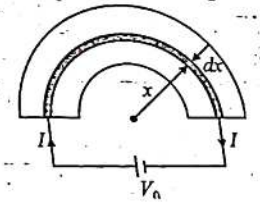
$$\frac{R_f}{R_i} = 1.001^2 = 1.002001$$

$R_f = R_i \times 1.002001$

Percentage increase in wire resistance

$$= \frac{1.002001 - 1}{1} \times 100\% = 0.2\%$$

28. (*a,c,d*) All the elements are in parallel



@IIT_KE_CBSE X @RAJ_SIR

$$\therefore \int \frac{1}{dr} = \int_{R_1}^{R_2} \frac{t\,dx}{\rho \pi x}$$

$$\frac{1}{r} = \frac{t}{\pi\rho} \ln\left(\frac{R_2}{R_1}\right)$$

$$\text{Resistance} = \frac{\pi\rho}{t \ell n\left(\frac{R_2}{R_1}\right)}$$

$$i = \frac{V_0 t \ln\left(\frac{R_2}{R_1}\right)}{\pi\rho} \quad ...(i)$$

$(-e\vec{E})$ will be inward direction in order to provide centripetal acceleration. Therefore, electric field will be radially outward

$V_{outer} < V_{Inner}$ ...(ii)

$$\frac{mv_d^2}{r} = qE$$

$$E = \frac{mv_d^2}{qr} \qquad (I = neAv_d \Rightarrow v_d \propto I)$$

$$\Delta V = \int \vec{E}.\overrightarrow{dr}$$

$\Delta V \propto v_d^2$

$\Delta V \propto I^2$

29. *(c)* The conductivity of a semi-conductor increases with increase in temperature i.e. resistivity ↓ with ↑ in temp. In a conducting solid, the collisions become more frequent with ↑ i.e. of temp. Hence, both *Y* and *Z* are true.

30. *(a,b,d)* At 0 K, a semiconductor becomes a perfect insulator. Therefore, at 0 K, if some potential difference is applied across an insulator or semiconductor, current is zero. But a conductor will become a super conductors at 0 K. Therefore, current will be infinite. In reverse biasing at 300 K through a p-n junction diode, a small finite current flows due to minority charge carriers.

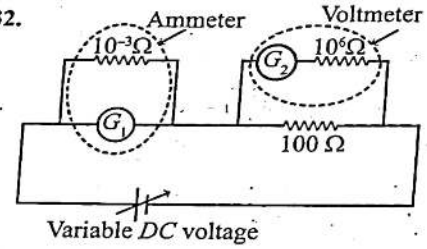
31. [False] The slope of the graph will provide us with the reciprocal of resistance.

The resistance at temperature T_1 is greater than the resistance at temperature T_2.

Because the resistance of metallic wire is greater at higher temperatures than at lower temperatures, $T_1 > T_2$.

Hence, the given statement is false.

32.



33. In series current is same. Therefore, from the relation $P = I^2R$, a bulb having more resistance consumes more power or glows brighter. 25W bulb has more resistance $\left(R = \frac{V^2}{P}\right)$ compared to 100 W bulb. Hence, it will glow brighter.

34. *(a)* $I^2Rt = m\,(S\,\Delta\theta)$

$$I^2\left(\rho_1 \cdot \frac{l}{A}\right)t = Al\rho_2\,(S\,\Delta\theta)$$

Here, ρ_1 = specific resistance and ρ_2 = density

$$\therefore \quad t = \frac{A^2\rho_2(S\Delta\theta)}{I^2\rho_1} \quad ...(i)$$

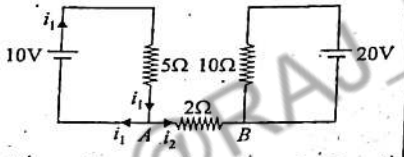
Substituting the values, we have

$$t = \frac{(0.5\times10^{-6})^2(9\times10^3)}{(9\times10^{-2}\times4.18\times1050)} \Big/ (1.0)^2(1.6\times10^{-8})$$

$= 55.5$ s

(b) From Eq. *(i)* we can see that time is independent of length of wire.

35. *(c)*



Assume i_1 current flows through 5Ω and i_2 current flows through 2Ω

Apply KVL

$10 - 5i_1 = 0$

$2A = i_1$

Apply KCL at junction *A*:

$i_1 = i_1 + i_2$

$i_2 = 0A$

36. *(d)* Since resistance of voltmeter is 400Ω, resistance viewed by voltmeter R_0 by using formula

$$\frac{1}{R_0} = \frac{1}{R} + \frac{1}{R_v}$$

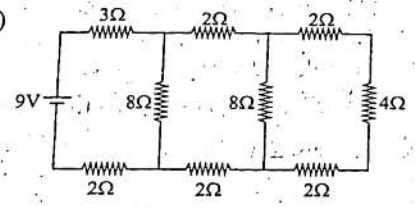
$R_v = 400\Omega$, $R = 400\Omega$, $R_0 = 200\Omega$

Hence the Middle 100Ω can be

$$V_{200\Omega} = \frac{200}{200+100} \times 10 = \frac{20}{3} V$$

Voltmeter resonances 20/3 *V*.

37. *(d)*



1. $R_{eq} = (4+2+2)\Omega = 8\Omega$

2. $R_{eq} = \frac{8\times8}{8+8}\Omega = 4\Omega$

3. $R_{eq} = (4+2+2)\Omega = 8\Omega$

4. $R_{eq} = \frac{8\times8}{8+8}\Omega = 4\Omega$

5. $R_{eq} = (4+2+3)\Omega = 9\Omega$

Hence, $V = IR$

$9V = I(9)\Omega$

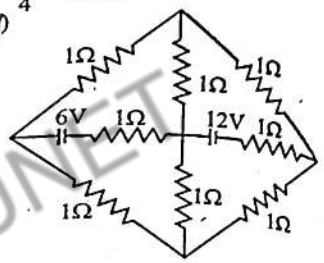
$I = 1A$

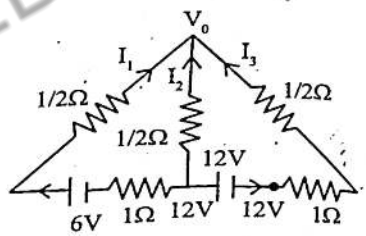
Current flowing through 3Ω resistor is $1A$.

Current flowing through 4Ω resistor is,

$$\frac{I}{4} = 0.25A$$

38. *(a,b,c,d)*





From KCL

$I_1 + I_2 + I_3 = 0$

$$\Rightarrow \frac{18-V_0}{\frac{3}{2}} + \frac{12-V_0}{\frac{1}{2}} + \frac{0-V_0}{\frac{3}{2}} = 0$$

$\Rightarrow 18 - V_0 + 36 - 3V_0 - V_0 = 0 \Rightarrow 54 = 5V_0$

$$\frac{2\left(\frac{54}{5} - v'\right)}{1} + \frac{18-v'}{1} = 0$$

$$\frac{108}{5} + 18 = 3v'$$

$$I_{R_1} = \frac{36}{5} = 7.2\,\text{A}$$

$$I_{R_2} = \frac{6}{5} = 1.2\,\text{A}$$

$$I_{R_3} = \frac{24}{5} = 4.8\,\text{A}$$

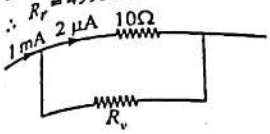
$$I_{R_4} = \frac{12}{5} = 2.4\,\text{A}$$

@FIKE_CBSE_ORAJ_EDUNET

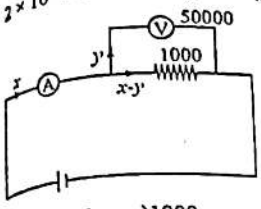
(a, c)

$0.1 = 2 \times 10^{-6}(10 + R_v)$

$\therefore R_v = 49990\ \Omega$



$2 \times 10^{-6} \times 10 = 10^{-3} R_A \quad \therefore \quad R_A = 0.02\ \Omega$

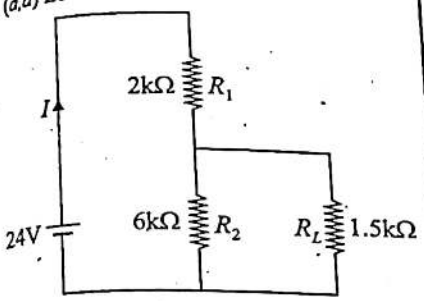


$50000y = (x - y)1000$

$\therefore 51y = x$

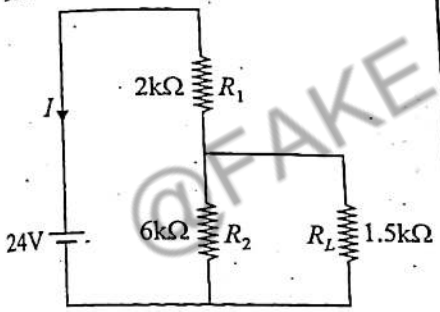
$$\text{Reading} = \frac{50000y}{x} = 980$$

(a,d) Let



On using the figure,

Total resistance be,



$$R_{eq} = \left(\frac{6 \times 1.5}{7.5} + 2\right) = \frac{6}{5} + 2 = \frac{16}{5} k\Omega$$

$$I = \frac{V}{R_{eq}} = \frac{24}{16} \times 5mA = \frac{3}{2} \times 5 = 7.5mA$$

For potential difference across R_1

$$V_1 = 7.5 \times 2 = 15V$$

For potential difference across R_2

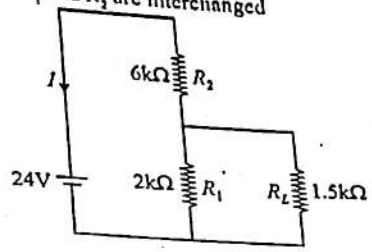
$$V_2 = 24 - 15 = 9V$$

For power $P_{R_1} : P_{R_2} = \frac{V_1^2}{R_1} : \frac{V_2^2}{R_2} = \frac{(15)^2}{2} : \frac{9^2}{6}$

$$= \frac{225}{2} \times \frac{6}{81} = \frac{25}{3}$$

$$P_{R_L} = \frac{V_2^2}{R_L} = \frac{9^2}{1.5} = 54mW$$

If R_1 and R_2 are interchanged



$$R' = R_1 \| R_2 = \left[\frac{(2)(1.5)}{2 + 1.5}\right] = \frac{3}{3.5}.$$

$$V_L = \frac{R'}{R_2 + R'} \times 24V = 3V$$

Now power dissipated in R_L is

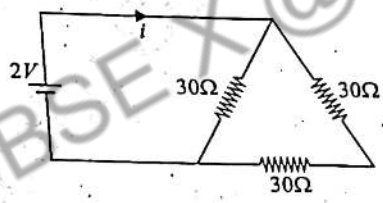
$$P'_L = \frac{V_L^2}{R_L} = \frac{3^2}{1.5} = 6mW$$

As, $P_{R_L} = 54mW$

$P'_L = 6\ mW$

$$\frac{P_L}{P'_L} = \frac{54}{6} = 9$$

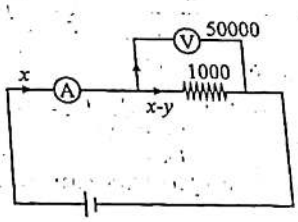
41. (c)



$$2V = \frac{30 \times 60}{30 + 60}(i)$$

$$\frac{1}{10} A = i$$

42. [5]

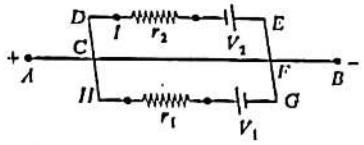


$$V_{AB} = \frac{\frac{15}{2}}{\frac{3}{2}} V$$

$$V_{AB} = 5V$$

43. The equivalent resistance, $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$

This is the internal resistance of a single battery that is the same as a parallel combination of two batteries. Now, in loop HCDEFGH, going clockwise from D, apply Kirchhoff's law.



$$-Ir_2 + V_2 + V_1 - Ir_1 = 0$$

$$I = \frac{V_1 + V_2}{r_1 + r_2}$$

$$V_A + Ir_1 - V_1 = V_B$$

$$V_A - V_B = V_1 - Ir_1$$

$$V_A - V_B = V_1 - \frac{(V_1 + V_2)r_1}{r_1 + r_2} = \frac{V_1 r_1 + V_1 r_2 - V_1 r_1 - V_2 r_1}{r_1 + r_2}$$

$$V_A - V_B = \frac{V_1 r_2 - V_2 r_1}{r_1 + r_2}$$

Hence, emf is $\frac{V_1 r_2 - V_2 r_1}{r_1 + r_2}$

and equivalent resistance is

$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

44. (i) **Step 1:** Determine the smallest repeating unit.

Step 2: Substitute R for the equivalent resistance.

The remaining circuit is identical to the first circuit after the first smallest repeating unit.

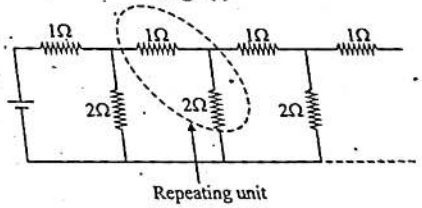
As a result, if the equivalent resistance between A and B is R, the remaining circuit's resistance will also be R, as indicated in the diagram.

Step 3: Find the resistance that is equal between A and B and equate it to R.

The equivalent resistance between A and B will be equal to the equivalent resistance of the whole circuit, as shown in the diagram. So, the resistance used in the circuit are 1Ω and 2Ω voltage. (V) = 6V

Here the resistors are in parallel also in series let the effective resistance is R.

Fig. (i)



@FAKE_CBSE_X @RAJ_EXUNET

Fig. (*ii*)

[∵ the cell is in discharging mode]

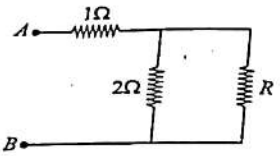
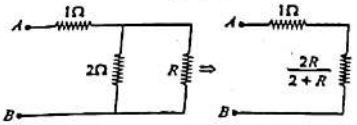


Fig. (*iii*)



The resistance $R\Omega$ a 2Ω are in parallel.

Combined Resistance is $R' = \frac{2R}{R+2}$

Total combined Resistance

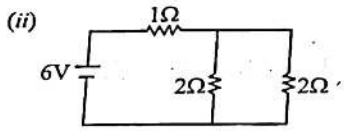
$$= \frac{2R}{R+2} + 1$$

$$\therefore R = \frac{2R}{R+2} + 1 = \frac{3R+2}{R+2}$$

$$R^2 + 2R = 3R + 2 \Rightarrow R^2 - R - 2 = 0$$

$$R = \frac{1 \pm \sqrt{1+8}}{2} = 2\Omega$$

(*ii*)



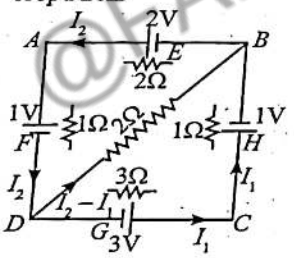
$$R_{eq} = 1 + \frac{2\times 2}{2+2} = 2\Omega$$

$$I = \frac{6}{R_{eq}} = \frac{6}{2} = 3A$$

Current through 2Ω resistor $= \frac{3\times 2}{4}$

$= 1 - 5$ A

45. Applying Kirchhoff's voltage law *KVL* in loop *BDAB*



$$2(I_2 - I_1) + 1 + 1 \times I_2 - 2 + 2I_2 = 0$$

$$\Rightarrow 2I_1 - 5I_2 = -1 \quad \ldots(i)$$

Applying Kirchhoffs law *KVL* in loop *BCDB*, we get

$$-2(I_2 - I_1) + 1 + I_1 - 3 + 3I_1 = 0$$

$$\Rightarrow 3I_1 - I_2 = 1 \quad \ldots(ii)$$

Solving eq. (*i*) and (*ii*), we get $I_1 = 6/13$ A and $I_2 = \frac{5}{13}$ A

(*i*) Potential difference between *B* and *D*,

$$V_B + \left[\frac{5}{13} - \frac{6}{13}\right] \times 2 = V_D$$

$$\therefore V_B - B_D = \frac{2}{13} \text{ V}$$

(*ii*) p.d. across

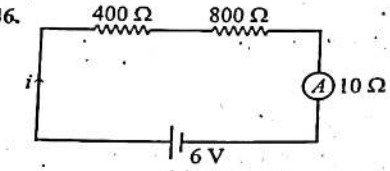
$$G = 3 - \frac{6}{13} \times 3 = \frac{39-18}{13} = \frac{21}{13} \text{ V}$$

[∵ the cell is in discharging mode]

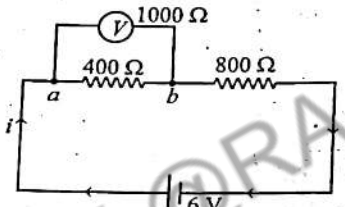
p.d. across $H = 1 + 1 \times \frac{6}{13} = \frac{19}{13}$ V

[∵ cell is in charging mode]

46.



(*a*)



(*b*)

Refer figure (*a*) Current through ammeter,

$$i = \frac{\text{net emf}}{\text{net resistance}} = \frac{6}{400+800+10}$$

$= 4.96 \times 10^{-3}$ A $= 4.96$mA

Refer figure (*b*) Combined resistance of 1000 Ω voltmeter and 400 Ω resistance is,

$$R = \frac{1000\times 400}{1000+400} = 285.71\ \Omega$$

$$\therefore i = \frac{6}{(285.71+800)} = 5.53 \times 10^{-3} \text{ A}$$

Reading of voltmeter

$= V_{ab} = i'R = (5.53 \times 10^{-3})(285.71)$

$= 1.58$ V

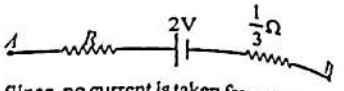
47. (*a*) Equivalent emf of three batteries would be

$$E_{eq} = \frac{\Sigma\left(\frac{E}{r}\right)}{\Sigma\left(\frac{1}{r}\right)} = \frac{\left(\frac{3}{1}+\frac{2}{1}+\frac{1}{1}\right)}{\left(\frac{1}{1}+\frac{1}{1}+\frac{1}{1}\right)}$$

$= 2$ V

Further r_1, r_2 and r_3 each are of 1 Ω. Therefore, internal resistance of the equivalent battery will be $\frac{1}{3}\Omega$, as all three are in parallel.

The equivalent circuit is therefore shown in the given figure.



Since, no current is taken from the battery.

$V_{AB} = E = 2$V (From $V = E - Ir$)

Further, $= V_{AB} = V_A - V_B = E_1 - I_1 r_1$

$$\therefore I_1 = \frac{V_B - V_A + E_1}{r_1} = \frac{-2+3}{1} = 1\text{A}$$

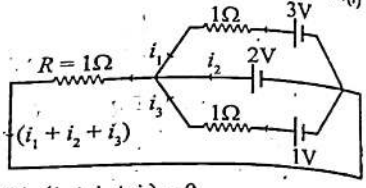
Similarly,

$$i_2 = \frac{V_B - V_A + E_2}{r_2} = \frac{-2+3}{1} = 0$$

and $i_3 = \frac{V_B - V_A + E_3}{r_3} = \frac{-2+1}{1} = -1$A

(*b*) r_2 is short circuited means resistance of this branch becomes zero. Making a closed circuit with a battery and resistance *R*. Applying Kirchhoff's second law in three loops so formed.

$$3 - i_1 - (i_1 + i_2 + i_3) = 0 \quad \ldots(i)$$



$$2 - (i_1 + i_2 + i_3) = 0 \quad \ldots(ii)$$

$$1 - i_3 - (i_1 + i_2 + i_3) = 0 \quad \ldots(iii)$$

From Eq. (*ii*) $i_1 + i_2 + i_3 = 2$A

Substituting in Eq. (*i*), we get,

$i_1 = 1$A

∴ Substituting in Eq. (*iii*) we get,

$i_3 = -1$A, $i_2 = 2$A

48. (*c*) Balanced condition for meter bridge,

$$\frac{X}{R} = \frac{l}{100-l}$$

given $R = 90\Omega$

$$\frac{X}{90} = \frac{40}{100-40}$$

$X = 60\Omega$

$$X = R\frac{l}{100-l}$$

$$\frac{\Delta X}{X} = \frac{\Delta l}{l} + \frac{\Delta l}{100-l} = \frac{0.1}{40} + \frac{0.1}{60}$$

$\Delta X = 0.25$

So, $X = (60 \pm 0.25)\Omega$

@FAKE_CBSE_X @RAJ_EDUNET

(a) Applying the condition of balanced Wheat stone bridge, we have,

$$\frac{P}{Q}=\frac{R}{S} \therefore \frac{X}{(52+1)}=\frac{10}{(48+2)}$$

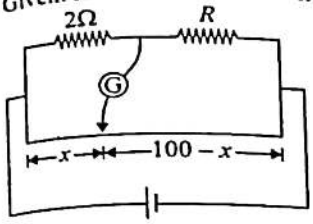
$$\therefore X=\frac{10\times 53}{50}=10.6\Omega$$

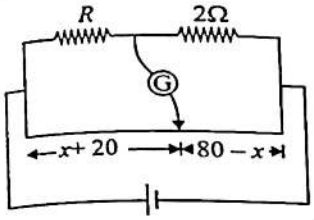
(d) If there is increase in temperature, then the value of unknown resistance will also increase. For balanced Wheat stone bridge condition, $\frac{R}{X}=\frac{l_1}{l_2}$

where, R = value of standard resistance, X = value of unknown resistance.

Here take null point at same point or l_1/l_2 to remain constant, R/X should also remain constant. Hence, if X is increasing R, should also increase.

(a) Given: $R>2\Omega \quad \therefore \quad 100-x>x$





According to balanced condition

$$\frac{P}{Q}=\frac{R}{S}$$

$$\frac{2}{R}=\frac{x}{100-x} \quad ...(i)$$

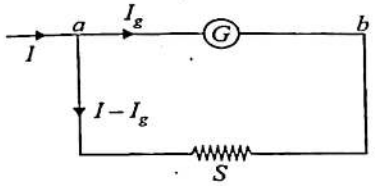
$$\frac{R}{2}=\frac{x+20}{80-x} \quad ...(ii)$$

Solving (*i*) & (*ii*) we get $R=3$.

52. (a) Voltage across shunt resistance

$V_{ab}=I_gG=(I-I_g)S$

$I=[1+(G/S)]I_g$



Here $s=0.1\Omega$, $G=100\Omega$, $I_g=100\ \mu A$

Substituting the values we get

$i=100.1$ mA.

53. (c) In this arrangement, the known resistance are BC, CD and BA. The unknown resistance is connected across the terminals A and D.

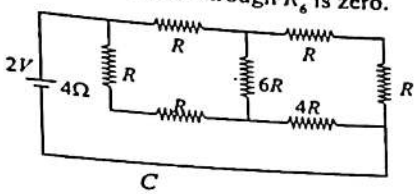
54. (a) The ratio AC/CB will remain the same.

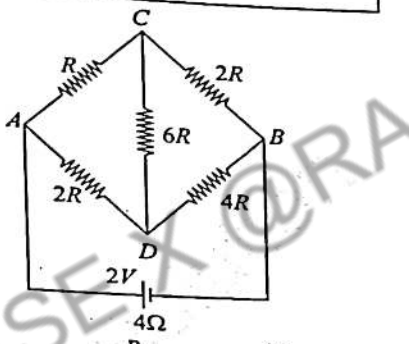
55. (c) As current I is independent of resistance R_6, therefore no current flows through R_6. For this to be done potential at junction joining R_1 and R_2 is same as that of potential at the junction joining R_3 and R_4. This is same as that of Wheatstone Bridge condition

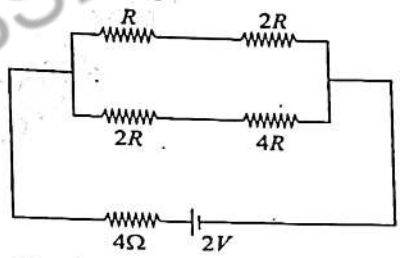
$$\Rightarrow \frac{R_1}{R_2}=\frac{R_3}{R_4} \Rightarrow R_1R_4=R_2R_3$$

Therefore current through R_6 is zero.

56. (b)







The given figure in the question is a balanced Wheat stone bridge which can be seen in figure 2. So no current flows through $6R$.

For maximum power

Net external resistance = internal resistance

From figure 3: $\frac{3R\times 6R}{3R+6R}=4$

$R=2\Omega$

57. (a) The reading of galvanometer is same weather the switch is open or closed, it means no current flows through switch. So we can remove switch S. It results R and G in series. Therefore same current flows through R and G.

58. (a, c) For maximum range of voltage resistance should be maximum. So, all four should be connected in series. For maximum range of current, net resistance should be least. Therefore, all four should be connected in parallel.

59. (a,b,c,d) Nodes P and Q are at same potential and also nodes S and T are at same potential due to formation of wheat stone bridge. So we can remove two 1Ω resistors.

$12\ V=R_{eq}I_1$

$$12V=\frac{12\times 6}{12+6}(I_1)$$

$$I_1=3A$$

$$I_2=I_1\left(\frac{12}{12+6}\right)$$

$$I_2=2A$$

In the resistor PS current flows from P to S. So P is at higher potential than S. As P and Q are at same potential. So Q is at higher potential than S.

Therefore potential at S is less than that at Q.

60. (b,c) To increase the range of ammeter a parallel resistance (called shunt) is required which is given by $S=\left(\frac{i_g}{i-i_g}\right)G$

For option (*c*)

$$S=\left(\frac{50\times 10^{-6}}{5\times 10^{-3}-50\times 10^{-6}}\right)(100)\approx 1\Omega$$

To change it in voltmeter, a high resistance R is put in series, where, R is given by

$$R=\frac{V}{i_g}-G$$

For option (*b*), $R=\frac{10}{50\times 10^{-6}}-100$

≈ 200 kΩ

Therefore, options (*b*) and (*c*) are correct.

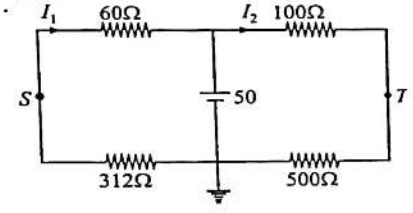
61. [5] $R_{AO}=\int_0^{1/2}\frac{\rho}{\pi}\frac{dx}{(r+4rx)^2}=\frac{2\rho}{3\pi r^2}$

$$R_{OB}=\int_{1/2}^{1}\frac{\rho}{\pi}\frac{dx}{(r+4rx)^2}=\frac{2\rho}{15\pi r^2}$$

$$(x)\frac{2\rho}{15\pi r^2}=(1)\frac{2\rho}{3\pi r^2}\Rightarrow x=5$$

62. [0.26 to 0.28] $R'_3=300(1+\alpha\Delta T)=312\ \Omega$

Now



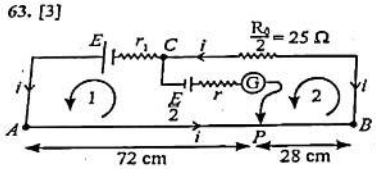
@FAKE_CBSE_X @RAJ_EDUNET

$I_1 = \frac{50}{372}$ and $I_2 = \frac{50}{600}$

$V_S - V_2 = 312\, I_1 - 500\, I_2$

$= 41.94 - 41.67 = -0.27$ V

63. [3]



$R_{AP} = 72 \times \frac{50}{100} = 36\Omega$,

$R_{PB} = 28 \times \frac{50}{100} = 14\Omega$

KVL Loop(1):

$-i(14) - i(25) + \frac{\varepsilon}{2} = 0$

$i = \frac{\varepsilon}{78}$ ...(i)

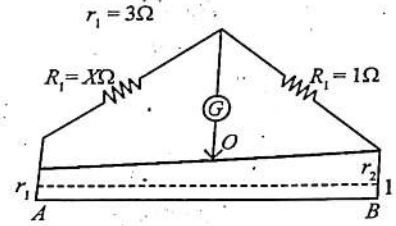
KVL loop (2).

$-ir_1 + E - iR_{AB} - \frac{\varepsilon}{2} = 0$

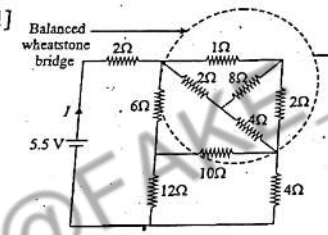
$-\frac{\varepsilon}{78} r_1 + \varepsilon - \frac{\varepsilon}{78} \cdot 36 - \frac{\varepsilon}{2} = 0$

$\frac{r_1}{78} = \frac{3}{78}$

$r_1 = 3\Omega$

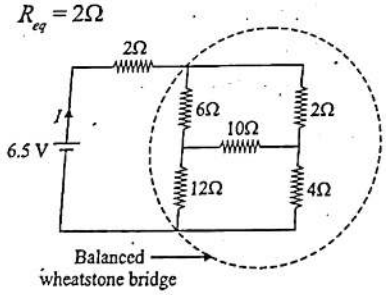


64. [1]



$R_{eq} = \frac{3 \times 6}{3+6}\Omega$

$R_{eq} = 2\Omega$

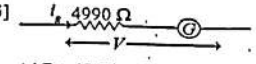


$R_{eq} = \frac{18 \times 6}{18+6}\Omega \Rightarrow R_{eq} = 4.5\Omega$

$6.5V = I(2 + 4.5)\Omega$

$1A = I$

65. [5]

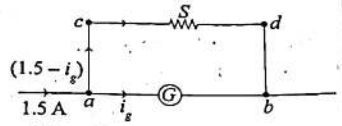


$i_g(G + 4990) = V$

$\Rightarrow \frac{6}{1000}(G + 4990) = 30$

$\Rightarrow G + 4990 = \frac{30000}{6} = 5000$

$\Rightarrow G = 10\,\Omega$



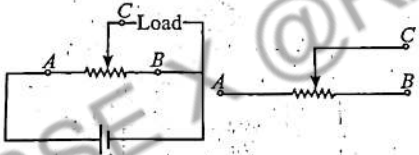
$\therefore V_{ab} = V_{cd} \Rightarrow i_g G = (1.5 - i_g) S$

$\Rightarrow \frac{6}{1000} \times 10 = \left(1.5 - \frac{6}{1000}\right) S$

$\Rightarrow S = \frac{60}{1494} = \frac{2n}{249}$

$\Rightarrow n = \frac{249 \times 30}{1494} = \frac{2490}{498} = 5$

66. The rheostat is as shown in figure. Battery should be connected between A and B and the load between C and B.



67. (*a*) After time t, thickness of liquid will remain $\left(\frac{d}{3} + vt\right)$

Now, time constant as function of time

$\tau_c = CR = \frac{\varepsilon_0(1) \cdot R}{\left(d - \frac{d}{3} + vt\right) + \frac{\frac{d}{3} - vt}{2}}$

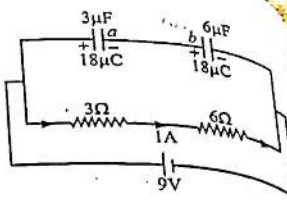
$\left(\text{Applying } C = \frac{\varepsilon_0 A}{d - t + \frac{t}{k}}\right)$

$= \frac{6\varepsilon_0 R}{5d + 3vt}$

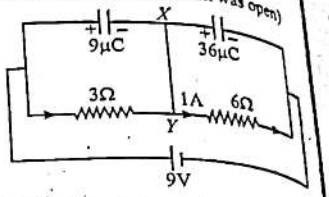
$\therefore$ Correct option is (*a*).

68. (*c*) From Y to X charge flows to plates a and b.

$(q_a + q_b)_i = 0, (q_a + q_b)_f = 27\mu C$



Initial figure (when switch was open)



Final figure (when switch is closed)

27 μC charge flows from Y to X.

$\therefore$ Correct option is (*c*).

NOTE In the initial figure, both capacitors are in series and total potential difference across them is 9 V. Therefore

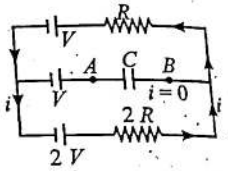
$q_{net} = C_{net} V_{net} = (2\mu F)(9V) = 18\mu C$

In the final figure.

$V_{3\mu F} = V_{3\Omega} = iR_3 = 3V$ and $V_{6\mu F} = V_{6\Omega} = iR_6$

Now, $q = CV$

69. (*c*) In steady state condition, no current will flow through the capacitor C. Current in the outer circuit,



$i = \frac{2V - V}{2R + R} = \frac{V}{3R}$

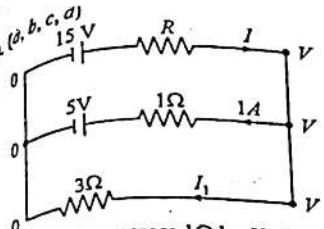
Potential difference between A and B:

$V_A - V + V + iR = V_B$

$\therefore V_B - V_A = iR = \left(\frac{V}{3R}\right) R = \frac{V}{3}$

NOTE: In this problem charge stored in the capacitor can also be asked, which is equal to $q = C\frac{V}{3}$ with positive charge on B side and negative on A side because $V_B > V_A$.

@FAKE_CBSE_Y @RAJ_FOUNET



Voltage drop across 1Ω be V, then

$0+5+1\times 1=V$

$V=6$

Voltage drop across R = Voltage drop across 1Ω.

$0+15-I\times R=6$

$IR=9$ ...(i)

$\Rightarrow$ Voltage drop across 3Ω = Voltage drop across 1Ω

$3I_1=6$

$I_1=2A$

So, option (*b*) is correct

From Kirchoff's current loop law,

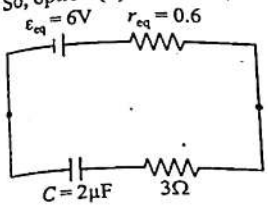
$\Rightarrow I=1+2$

$I=3$

From eq^n(*i*)

$R=3\Omega$

So, option (*a*) is correct.



$$\frac{1}{r_{eq}}=\frac{1}{3}+1+\frac{1}{3}\Rightarrow r_{eq}=0.6\Omega$$

$$\varepsilon_{eq}=\frac{\frac{15}{3}+\frac{5}{1}+\frac{0}{3}}{\frac{1}{3}+\frac{1}{1}+\frac{1}{3}}=10\times\frac{3}{5}=6V$$

$q_{max}=C\varepsilon_{eq}=2\times 6=12\ \mu C$

Time constant, $\tau=RC=(3+0.6)\times 2$

$=7.2\ \mu s$

$$\therefore\ i=\frac{6}{3+0.6}e^{-\frac{t}{\tau}}$$

$$=\frac{5}{3}e^{-\frac{7.2}{7.2}}=\frac{5}{3}e^{-1}\approx 0.6A$$

71. (*a,b,c,d*) Writing instantaneous equation, with q_1 being charge on upper and q_2 being that on lower capacitor,

$q_1=(200\times 10^{-3})(1-e^{-t})$

$q_2=(100\times 10^{-3})(1-e^{-t})$

$\frac{q_1}{C}=(50\times 10^3)\frac{dq_2}{dt}$

$\frac{200\times 10^{-3}(1-e^{-t})}{40\times 10^{-6}}=(50\times 10^3)(100\times 10^{-3})e^{-t}$

$e^{-t}=0.5$

$t=\ln(2)$

$I=I_1+I_2=(200\times 10^{-3})(e^{-t})+(100\times 10^{-3})e^{-t}$

$=100\times 10^{-3}[2e^{-t}+e^{-t}]=0.3e^{-t}$

$t=\infty,\ I=0$

72. [1.33] After long time we can replace the capacitor by open circuit.

i current in circuit = 1/3 ampere

Potential across capacitor

$$=2-2\left(\frac{1}{3}\right)=\frac{4}{3}\text{ volt}$$

Potential difference across capacitor

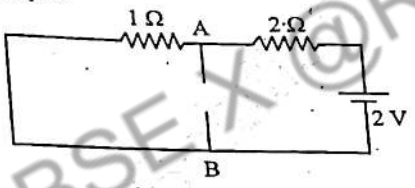
$$\Delta V=\frac{4}{3}\text{volt}$$

$\therefore$ Charge on capacitor, $q_1=C\Delta V$

$$=1\times\frac{4}{3}\mu C$$

$q_1=1.33\ \mu C$

73. [0.67] After long time i in circuit $=\frac{2}{3}$ ampere



$$V_A-V_B=i_2\times 1=\frac{2}{3}V$$

Potential difference across capacitor

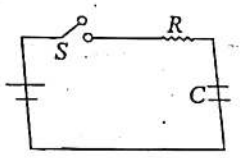
$$\Delta V=\frac{2}{3}\text{ volt}$$

$\therefore$ Charge on capacitor $q_2=C\Delta V$

$$=1\times\frac{2}{3}=0.67\mu C$$

74. (*b*) When switch is closed for a very long time capacitor will get fully charged and charge on capacitor will be $q=CV$

Energy stored in capacitor, $E_C=\frac{1}{2}CV^2$ ...(i)



Work done by a battery, $W=Vq$

$=VCV=CV^2$

Energy dissipated across resistance

$E_D=$ (work done by battery) − (energy stored)

$$E_D=CV^2-\frac{1}{2}CV^2=\frac{1}{2}CV^2 \quad ...(ii)$$

From Eqs. (*i*) and (*ii*)

$E_D=E_C$

75. (*a*) **Step-1**

Charge on capacitor $=\frac{CV_0}{3}$

Energy stored in capacitor

$$=\frac{1}{2}C\frac{V_0^2}{9}=\frac{CV_0^2}{18}$$

Work done by battery

$$=\frac{CV_0}{3}\times\frac{V_0}{3}=\frac{CV_0^2}{9}$$

$\therefore$ Heat loss $=\frac{CV_0^2}{9}-\frac{CV_0^2}{18}=\frac{CV_0^2}{18}$

Step-2

Charge on capacitor $=\frac{2CV_0}{3}$

Extra charge flown through the battery

$$=\frac{CV_0}{3}$$

Work done by battery

$$=\frac{CV_0}{3}\cdot\frac{2V_0}{3}=\frac{2CV_0^2}{9}$$

Final energy stored in capacitor

$$=\frac{1}{2}C\left(\frac{2V_0}{3}\right)^2=\frac{4CV_0^2}{18}$$

Extra energy stored in Step-2

$$=\frac{4CV_0^2}{18}-\frac{CV_0^2}{18}=\frac{3CV_0^2}{18}$$

Heat loss in Step-2 = work done by battery in Step-2 − extra energy stored in capacitor in Step-2

$$=\frac{2CV_0^2}{9}-\frac{3CV_0^2}{18}=\frac{CV_0^2}{18}$$

Step-3 Charge on capacitor $=CV_0$

Extra charge flown through battery

$$=CV_0-\frac{2CV_0}{3}=\frac{CV_0}{3}$$

Work done by battery in this step

$$=\left(\frac{CV_0}{3}\right)(V_0)=\frac{CV_0^2}{3}$$

Final energy stored in capacitor

$$=\frac{1}{2}CV_0^2$$

@FAKE_CBSE_X @RAJ_EDUNET

extra energy stored in this step

$$=\frac{1}{2}CV_0^2-\frac{4CV_0^2}{18}=\frac{5CV_0^2}{18}$$

Heat loss in Step-3

$$=\frac{CV_0^2}{3}-\frac{5CV_0^2}{18}=\frac{CV_0^2}{18}$$

Now, total heat loss

$$(E_D)=\frac{CV_0^2}{18}+\frac{CV_0^2}{18}+\frac{CV_0^2}{18}=\frac{CV_0^2}{6}$$

$$=\frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$$

76. [2] Voltage across the capacitors will increase from 0 to 10 V exponentially. The voltage at time t will be given by

$V=10(1-e^{-t/\tau_c})$

Here, $\tau_c=C_{net}R_{net}$

$=(1\times10^6)(4\times10^{-6})=4s$

$\therefore\ V=10(1-e^{-t/4})$

Substituting $V=4$ volt, we have

$4=10(1-e^{-t/4})$

or $e^{-t/4}=0.6=\frac{3}{5}$

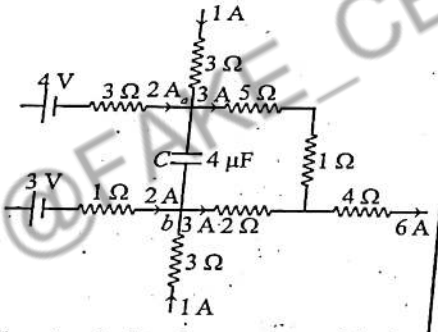
Taking log on both sides we have,

$-\frac{t}{4}=\ln 3-\ln 5$

or $t=4(\ln 5-\ln 3)=2$ s

Hence, the answer is 2.

77. [0.288] Using Kirchhoff's first law at junctions a and b, we can find the currents in other wires of the circuit.



Now, to calculate the energy stored in the capacitor we will have to first find the potential difference V_{ab} across it.

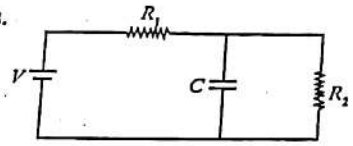
$V_a-3\times5-3\times1+2\times2=V_b$

$\therefore\ V_a-V_b=V_{ab}=12$ V

$\therefore\ U=\frac{1}{2}CV_{ab}^2=\frac{1}{2}(4\times10^{-6})(12)^2$ J

$=0.288$ mJ

78.



Q_0 is the steady state charge stored in the capacitor.

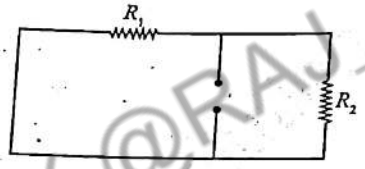
$Q_0=C$ [potential difference across capacitor in steady state]

$=C$ [steady state current through R_2] (R_2)

$=C\left(\frac{V}{R_1+R_2}\right)\cdot R_2$

$Q_0=\frac{CVR_2}{R_1+R_2}$

$\alpha=\frac{1}{CR_{net}}$



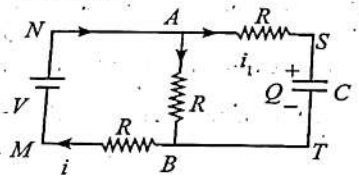
Here, R_{net} is equivalent resistance across capacitor after short circuiting the battery. Thus,

$R_{net}=\frac{R_1R_2}{R_1+R_2}$

(As R_1 and R_2 are in parallel)

$\alpha=\frac{1}{C\left(\frac{R_1R_2}{R_1+R_2}\right)}=\frac{R_1+R_2}{CR_1R_2}$

79. Let at any time t charge on capacitor C be Q and currents are as shown in figure. Since, charge Q will increase with time t. Therefore,



$I_1=\frac{dQ}{dt}$

(a) Applying Kirchhoff 's second law in loop $MNABM$

$V=(I-I_1)R+IR$

or $V=2IR-I_1R$ ...(i)

Similarly, applying Kirchhoff 's second law in loop $MNSTM$, we have

$V=I_1R+\frac{Q}{C}+IR$ ...(ii)

Eliminating I from Eqs. (i) and (ii), we get

$V=3I_1R+\frac{2Q}{C}$ or $3I_1R=V-\frac{2Q}{C}$

or $I_1=\frac{1}{3R}\left(V-\frac{2Q}{C}\right)$

or $\frac{dQ}{dt}=\frac{1}{3R}\left(V-\frac{2Q}{C}\right)$

or $\frac{dQ}{V-\frac{2Q}{C}}=\frac{dt}{3R}$

or $\int_0^Q\frac{dQ}{V-\frac{2Q}{C}}=\int_0^t\frac{dt}{3R}$

This equation gives

$Q=\frac{CV}{2}(1-e^{-2t/3RC})$

(b) $i_1=\frac{dQ}{dt}=\frac{V}{3R}e^{-2t/3RC}$

From Eq. (i)

$i=\frac{V+i_1R}{2R}=\frac{V+\frac{V}{3}e^{-2t/3RC}}{2R}$

$\therefore$ Current through AB

$i_2=i-i_1=\frac{V+\frac{V}{3}e^{-2t/3RC}}{2R}-\frac{V}{3R}e^{-2t/3RC}$

$i_2=\frac{V}{2R}-\frac{V}{6R}e^{-2t/3RC}$

$i_2=\frac{V}{2R}$ as $t\to\infty$

@FAKE_CBSE_@RAJ_EDUNET

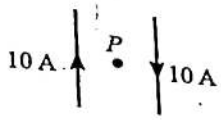
20 Moving Charges and Magnetism

Scan for ⦿ Sol.

JEE-Main

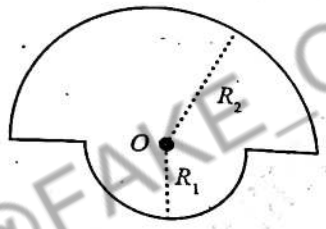
Biot Savart Law, Magnetic field due to current carrying wire

1. Two long, straight wires carry equal currents in opposite directions as shown in figure. The separation between the wires is 5.0 cm. The magnitude of the magnetic field at a point P midway between the wires is ____ μT
(Given: $\mu_0 = 4\pi \times 10^{-7}$ TmA^{-1})



[27 Jan, 2024 (Shift-I)]

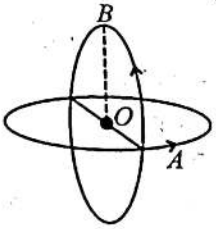
2. The magnetic field at the centre of a wire loop formed by two semicircular wires of radii $R_1 = 2\pi$ m and $R_2 = 4\pi$ m carrying current $I = 4$A as per figure given below is $\alpha \times 10^{-7}$ T. The value of α is ____. (Centre O is common for all segments)



[27 Jan, 2024 (Shift-II)]

3. Two insulated circular loop A and B radius 'a' carrying a current of 'I' in the anti clockwise direction as shown in figure. The magnitude of the magnetic induction at the centre will be :

[30 Jan, 2024 (Shift-I)]



(a) $\frac{\sqrt{2}\mu_0 I}{a}$ (b) $\frac{\mu_0 I}{2a}$ (c) $\frac{\mu_0 I}{\sqrt{2}a}$ (d) $\frac{2\mu_0 I}{a}$

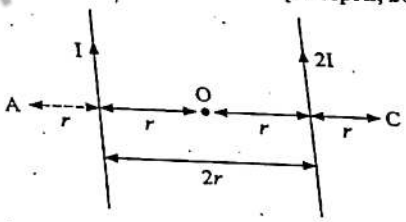
4. The current of 5A flows in a square loop of sides 1 m is placed in air. The magnetic field at the centre of the loop is $X\sqrt{2}\times10^{-7}$ T. The value of X is ____.

[30 Jan, 2024 (Shift-II)]

5. A regular polygon of 6 sides is formed by bending a wire of length 4π meter. If an electric current of $4\pi\sqrt{3}$ A is flowing through the sides of the polygon, the magnetic field at the centre of the polygon would be $x \times 10^{-7}$ T. The value of x is ____. [1 Feb, 2024 (Shift-I)]

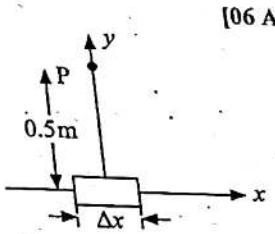
6. Two parallel long current carrying wire separated by a distance $2r$ are shown in the figure. The ratio of magnetic field at A to the magnetic field produced at C is $\frac{x}{7}$. The value of x is ____.

[04 April, 2024 (Shift-II)]



7. An element $\Delta l = \Delta x\hat{i}$ is placed at the origin and carries a large current $I = 10$A. The magnetic field on the y-axis at a distance of 0.5 m from the elements Δx of 1 cm length is:

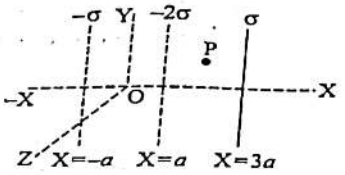
[06 April, 2024 (Shift-I)]



(a) 4×10^{-8}T (b) 8×10^{-8}T
(c) 12×10^{-8}T (d) 10×10^{-8}T

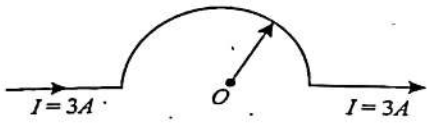
8. Three infinitely long charged thin sheets are placed as shown in figure. The magnitude of electric field at the point P is $\frac{x\sigma}{\varepsilon_0}$. The value of x is _____ [06 April, 2024 (Shift-I)]
(all quantities are measured in SI units).

@FAKE_CBSE_X @RAJ_EDUNET



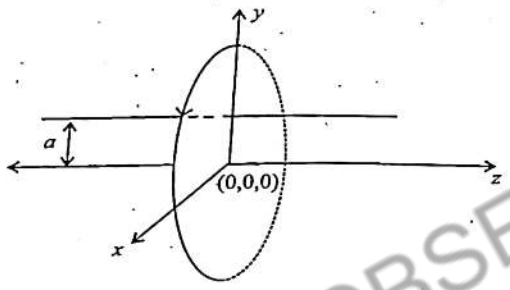
9. As shown in the figure, a long straight conductor with semicircular arc of radius $\frac{\pi}{10}m$ is carrying current $I = 3A$. The magnitude of the magnetic field at the center O of the arc is:
(The permeability of the vacuum $= 4\pi \times 10^{-7} NA^{-2}$)

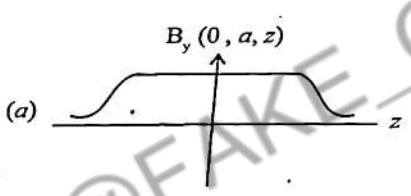
[1 Feb, 2023 (Shift-II)]

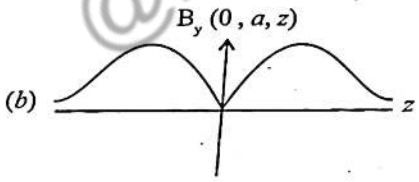


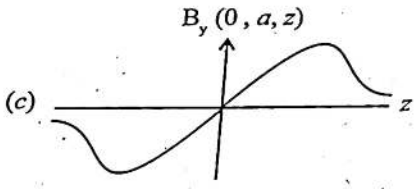
(a) $6\mu T$ (b) $1\mu T$ (c) $4\mu T$ (d) $3\mu T$

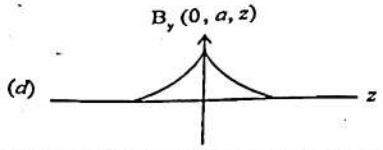
10. A single current carrying loop of wire carrying current I flowing in anticlockwise direction as seen from +ve z direction and lying in xy plane is shown in figure. The plot of $\hat{j}$ component of magnetic field (B_y) at a distance 'a' (less than radius of the coil) and on yz plane vs z coordinate look like **[29 Jan, 2023 (Shift-I)]**



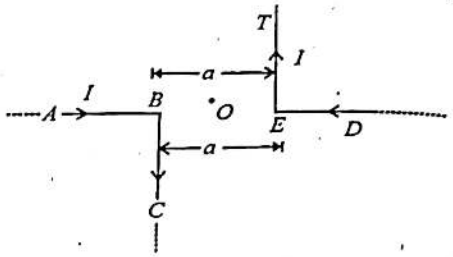
(a)


(b)


(c)


(d)


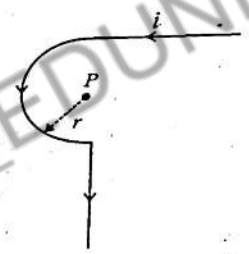
11. The magnitude of magnetic induction at mid-point O due to current arrangement as shown in the Fig will be: **[29 Jan, 2023 (Shift-I)]**



(a) $\frac{\mu_0 I}{2\pi a}$ (b) 0 (c) $\frac{\mu_0 I}{4\pi a}$ (d) $\frac{\mu_0 I}{\pi a}$

12. Find the magnetic field at the point P in figure. The curved portion is a semicircle connected to two long straight wires.

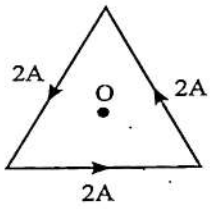
[1 Feb, 2023 (Shift-I)]



(a) $\frac{\mu_0 i}{2r}\left(1+\frac{2}{\pi}\right)$ (b) $\frac{\mu_0 i}{2r}\left(1+\frac{1}{\pi}\right)$

(c) $\frac{\mu_0 i}{2r}\left(\frac{1}{2}+\frac{1}{2\pi}\right)$ (d) $\frac{\mu_0 i}{2r}\left(\frac{1}{2}+\frac{1}{\pi}\right)$

13. As shown in the figure, a current of 2A flows in an equilateral triangle of side $4\sqrt{3}$ cm. The magnetic field at the centroid O of the triangle is: **[30 Jan, 2023 (Shift-II)]**



(Neglect the effect of earth's magnetic field.)

(a) $4\sqrt{3}\times10^{-4}$ T (b) $4\sqrt{3}\times10^{-5}$ T

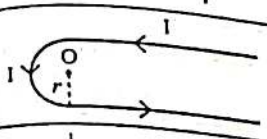
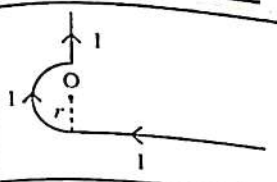
(c) $\sqrt{3}\times10^{-4}$ T (d) $3\sqrt{3}\times10^{-5}$ T

14. A circular loop of radius r is carrying current I A. The ratio of magnetic field at the centre of circular loop and at a distance r from the center of the loop on its axis is: **[24 Jan, 2023 (Shift-I)]**

(a) $1:3\sqrt{2}$ (b) $3\sqrt{2}:2$ (c) $2\sqrt{2}:1$ (d) $1:\sqrt{2}$

@FAKE_CBSE X @RAJ_EDUNET

15. Match List-I with List-II [25 Jan, 2023 (Shift-I)]

List - I (Current Configuration)		List - II (Magnetic field at point O)	
A		I.	$B_0 = \frac{\mu_0 I}{4\pi r}[\pi + 2]$
B		II.	$B_0 = \frac{\mu_0}{4}\frac{I}{r}$
C		III.	$B_0 = \frac{\mu_0 I}{2\pi r}[\pi - 1]$
D		IV.	$B_0 = \frac{\mu_0 I}{4\pi r}[\pi + 1]$

Choose the correct answer from the option given below:

(a) A-III, B-IV, C-I, D-II (b) A-I, B-III, C-IV, D-II

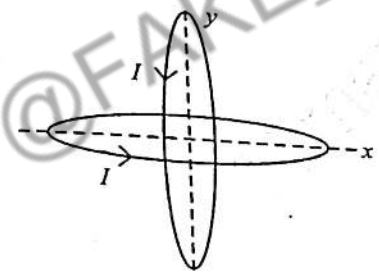
(c) A-III, B-I, C-IV, D-II (d) A-II, B-I, C-IV, D-III

16. Two long parallel wires carrying currents 8 A and 15 A in opposite directions are placed at a distance of 7 cm from each other. A point P is equidistant from both the wires such that the lines joining the point P to the wires are perpendicular to each other. Magnitude of the magnetic field at P is _____ $\times 10^{-6}$ T. (Given: $\sqrt{2} = 1.4$)

[25 Jan, 2023 (Shift-II)]

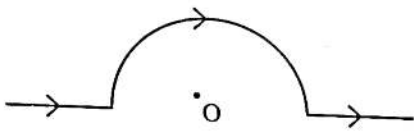
17. Two identical circular wires of radius 20 cm and carrying current $\sqrt{2}\,A$ are placed in perpendicular planes as shown in figure. The net magnetic field at the centre of the circular wire is _____ $\times 10^{-8}$ T. (Take $\pi = 3.14$

[6 April, 2023 (Shift-I)]



18. A straight wire carrying a current of 14 A is bent into a semicircular arc of radius 2.2 cm as shown in the figure. The magnetic field produced by the current at the centre (O) of the arc. is _____ $\times 10^{-4}$ T

[10 April, 2023 (Shift-II)]



19. An electron in a hydrogen atom revolves around its nucleus with a speed of 6.76×10^6 ms^{-1} in an orbit of radius 0.52Å. The magnetic field produced at the nucleus of the hydrogen atom is _____ T.

[15 April, 2023 (Shift-I)]

20. The ratio of magnetic field at the centre of a current carrying coil of radius r to the magnetic field at distance r from the centre of coil on its axis is $\sqrt{x}:1$. The value of x is_____.

[8 April, 2023 (Shift-II)]

21. Two long current carrying conductors are placed parallel to each other at a distance of 8 cm between them. The magnitude of magnetic field produced at mid-point between the two conductors due to current flowing in them is 300 μT. The equal current flowing in the two conductors is: [29 June, 2022 (Shift-II)]

(a) 30A in the same direction.

(b) 30 A in the opposite direction.

(c) 60A in the opposite direction.

(d) 300A in the opposite direction.

22. The magnetic field at the centre of current carrying circular loop is B_1.The magnetic field at a distance of $\sqrt{3}$ times radius of the given circular loop from the center on its axis is B_2. The value of B_1/B_2 will be

[28 July, 2022 (Shift-II)]

(a) 9 : 4 (b) $12:\sqrt{5}$ (c) 8 : 1 (d) $5:\sqrt{3}$

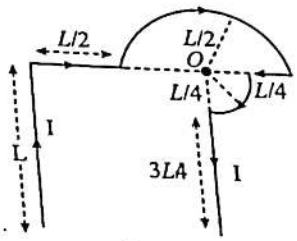
23. The magnetic field at the centre of a circular coil of radius r, due to current I flowing through it, is B. The magnetic field at a point along the axis at a distance $r/2$ from the centre is:

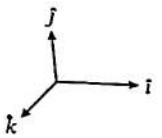
[24 June, 2022 (Shift-I)]

(a) $B/2$ (b) $2B$ (c) $\left(\frac{2}{\sqrt{5}}\right)^3 B$ (d) $\left(\frac{1}{\sqrt{3}}\right)^3 B$

24. Which one of the following options represents the magnetic field $\vec{B}$ at O due to the current flowing in the given wire segments lying on the xy plane?

[JEE Adv, 2022]





(a) $\vec{B} = \frac{-\mu_0 I}{L}\left(\frac{3}{2} + \frac{1}{4\sqrt{2}\pi}\right)\hat{k}$ (b) $\vec{B} = -\frac{\mu_0 I}{L}\left(\frac{3}{2} + \frac{1}{2\sqrt{2}\pi}\right)\hat{k}$

(c) $\vec{B} = \frac{-\mu_0 I}{L}\left(1 + \frac{1}{4\sqrt{2}\pi}\right)\hat{k}$ (d) $\vec{B} = \frac{-\mu_0 I}{L}\left(1 + \frac{1}{4\pi}\right)\hat{k}$

25. A coil having N turns is would tightly in the form of a spiral with inner and outer radii 'a' and 'b' respectively. Find the magnetic field at centre, when a current I passes through coil:

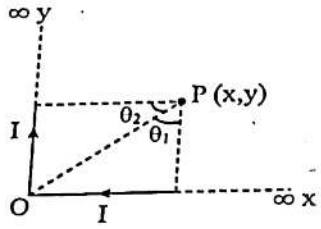
[31 Aug, 2021 (Shift-I)]

(a) $\frac{\mu_0 I}{8}\left[\frac{a+b}{a-b}\right]$ (b) $\frac{\mu_0 IN}{2(b-a)}\log_e\left(\frac{b}{a}\right)$

(c) $\frac{\mu_0 I}{4(a-b)}\left[\frac{1}{a} - \frac{1}{b}\right]$ (d) $\frac{\mu_0 I}{8}\left(\frac{a-b}{a+b}\right)$

@FAKE_CBSE_X_@NV_ETWNET

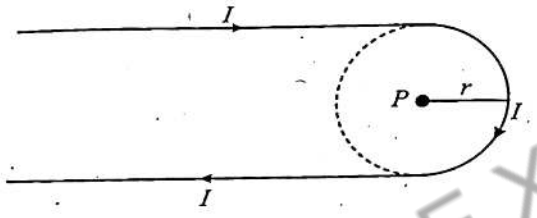
26. There are two infinitely long straight current carrying conductors and they are held at right angles to each other so that their common ends meet at the origin as shown in the figure given below. The ratio of current in both conductor is 1 : 1. The magnetic field at point P is
[1 Sept, 2021 (Shift-II)]



(a) $\frac{\mu_0 I}{4\pi xy}\left[\sqrt{x^2+y^2}-(x+y)\right]$ (b) $\frac{\mu_0 I}{4\pi xy}\left[\sqrt{x^2+y^2}+(x+y)\right]$

(c) $\frac{\mu_0 Ixy}{4\pi}\left[\sqrt{x^2+y^2}-(x+y)\right]$ (d) $\frac{\mu_0 Ixy}{4\pi}\left[\sqrt{x^2+y^2}+(x+y)\right]$

27. A hairpin like shape as shown in figure is made by bending a long current carrying wire. What is the magnitude of a magnetic field at point P which lies on the centre of the semicircle?
[17 March, 2021 (Shift-II)]



(a) $\frac{\mu_0 I}{2\pi r}(2-\pi)$ (b) $\frac{\mu_0 I}{4\pi r}(2-\pi)$

(c) $\frac{\mu_0 I}{2\pi r}(2+\pi)$ (d) $\frac{\mu_0 I}{4\pi r}(2+\pi)$

28. A current of 1.5 A is flowing through a triangle, of side 9 cm each. The magnetic field at the centroid of the triangle is:
(Assume that the current is flowing in the clockwise direction.)
[31 Aug, 2021 (Shift-II)]

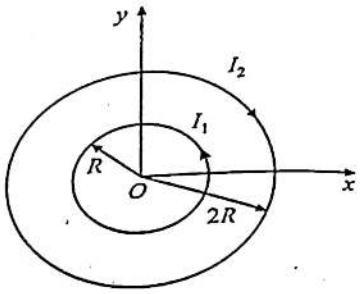
(a) $2\sqrt{3}\times10^{-7}\,T$, outside the plane of triangle

(b) $2\sqrt{3}\times10^{-5}\,T$, inside the plane of triangle

(c) $3\times10^{-5}\,T$, inside the plane of triangle

(d) $3\times10^{-7}\,T$, outside the plane of triangle

29. Two concentric circular loops, one of radius R and the other of radius $2R$, lie in the xy-plane with the origin as their common center, as shown in the figure. The smaller loop carries current I_1 in the anti-clockwise direction and the larger loop carries current I_2 in the clockwise direction, with $I_2 > 2I_1$. $\vec{B}(x, y)$ denotes the magnetic field at a point (x, y) in the xy-plane. Which of the following statement(s) is(are) correct?
[JEE Adv, 2021]



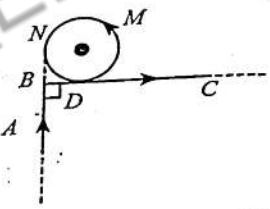
(a) $\vec{B}(x,y)$ is perpendicular to the xy-plane at any point in the plane.

(b) $|\vec{B}(x,y)|$ depends on x and y only through the radial distance $r=\sqrt{x^2+y^2}$.

(c) $|\vec{B}(x,y)|$ is non-zero at all points for $r < R$.

(d) $\vec{B}(x,y)$ points normally outward from the plane for all the points between the two loops.

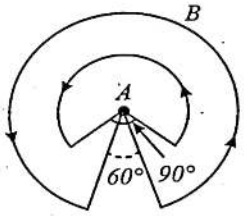
30. A very long wire ABDMNDC is shown in figure carrying current I. AB and BC parts are straight, long and at right angle. At D wire forms a circular turn $DMND$ of radius R. AB, BC parts are tangential to circular turn at N and D. Magnetic field at the centre of circle is:
[8 Jan, 2020 (Shift-II)]



(a) $\frac{\mu_0 I}{2R}$ (b) $\frac{\mu_0 I}{2\pi R}\left(\pi-\frac{1}{\sqrt{2}}\right)$

(c) $\frac{\mu_0 I}{2\pi R}(\pi+1)$ (d) $\frac{\mu_0 I}{2\pi R}\left(\pi+\frac{1}{2}\right)$

31. A wire A, bent in the shape of an arc of a circle, carrying a current of 2 A and having radius 2 cm and another wire B, also bent in the shape of arc of a circle, carrying a current of 3 A and having radius of 4 cm, are placed as shown in the figure. The ratio of the magnetic fields due to the wires A and B at the common centre O is
[04 Sep, 2020 (Shift-I)]



(a) 2 : 5 (b) 6 : 5 (c) 4 : 6 (d) 6 : 4

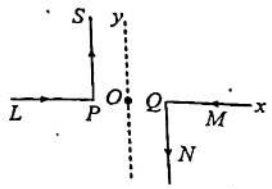
32. One of the two identical conducing wires of length L is bent in the form of a circular loop and the other one into a circular coil of N

@FAKE_CBSE_X_@RAJ_EDUCATION_NET

identical turns. If the same current is passed in both, the ratio of the magnetic field at the central of the loop (B_L) to that at the centre of the coil (B_C), i.e. $\frac{B_L}{B_C}$ will be **[9 Jan, 2019 (Shift-II)]**

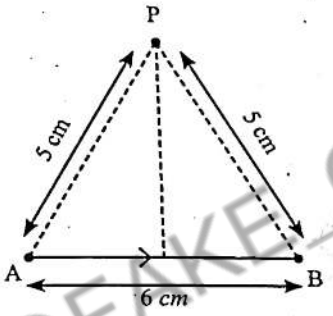
(a) N (b) $\frac{1}{N}$ (c) N^2 (d) $\frac{1}{N^2}$

33. As shown in the figure, two infinitely long, identical wires are bent by 90° and placed in such a way that the segments LP and QM are along the x-axis, while segments PS and QN are parallel to the y-axis. If $OP = OQ = 4$ cm, and the magnitude of the magnetic field at O is 10^{-4} T, and the two wires carry equal current (see figure), the magnitude of the current in each wire and the direction of the magnetic field at O will be ($\mu_0 = 4\pi \times 10^{-7}$ NA^{-2})
[12 Jan, 2019 (Shift-I)]



(a) 20 A, perpendicular out of the page.
(b) 40 A, perpendicular out of the page.
(c) 20 A, perpendicular into the page.
(d) 40 A, perpendicular into the page.

34. Find the magnetic field at point P due to a straight line segment AB of length 6 cm carrying a current of 5 A. (See figure) ($\mu 0 = 4p \times 10^{-7} N - A - 2$) **[12 April, 2019 (Shift-II)]**

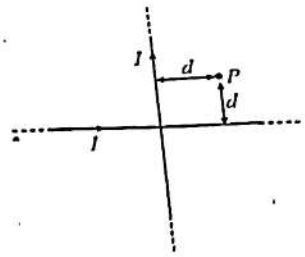


(a) 35.0×10^{-5} T (b) 3.0×10^{-5} T
(c) 2.5×10^{-5} T (d) 1.5×10^{-5} T

35. A thin ring of 10 cm radius carries a uniformly distributed charge. The ring rotates at a constant angular speed of 40π rads^{-1} about its axis, perpendicular to its plane. If the magnetic field at its centre is 3.8×10^{-9} T, then the charge carried by the ring is close to ($\mu_0 = 4\pi \times 10^{-7}$ N/A^2). **[12 April, 2019 (Shift-I)]**

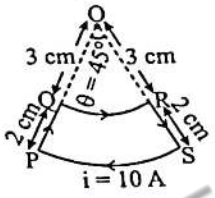
(a) 2×10^{-6} C (b) 7×10^{-6} C (c) 4×10^{-5} C (d) 3×10^{-7} C

36. Two very long, straight and insulated wires are kept at 90° angle from each other in xy-plane as shown in the figure. These wires carry currents of equal magnitude I, whose directions are shown in the figure. The net magnetic field at point P will be **[8 April, 2019 (Shift-II)]**



(a) Zero (b) $\frac{+\mu_0 I}{\pi d}(\hat{z})$
(c) $-\frac{\mu_0 I}{2\pi d}(\hat{x}+\hat{y})$ (d) $\frac{\mu_0 I}{2\pi d}(\hat{x}+\hat{y})$

37. A current loop, having two circular arcs joined by two radial lines is shown in the figure. It carries a current of 10 A. The magnetic field at point O will be close to: **[9 Jan, 2019 (Shift-I)]**



(a) $39..0 \times 10^{-7}$ T (b) 1.5×10^{-7} T
(c) 1.5×10^{-5} T (d) 1.0×10^{-5} T

Ampere's Circuital Law and Its Applications

38. Two circular coils P and Q of 100 turns each have same radius of π cm. The currents in P and R are 1 A and 2 A respectively. P and Q are placed with their planes mutually perpendicular with their centers coincide. The resultant magnetic field induction at the center of the coils is $\sqrt{x}mT$, where x = _____.
[Use $\mu_0 = 4\pi \times 10^{-7}$ TmA^{-1}] **[31 Jan, 2024 (Shift-II)]**

39. In a co-axial straight cable, the central conductor and the outer conductor carry equal currents in opposite directions. The magnetic field is zero. **[05 April, 2024 (Shift-I)]**
(a) inside the outer conductor
(b) in between the two conductors
(c) outside the cable
(d) inside the inner conductor

40. A solenoid of length 0.5 m has a radius of 1 cm and is made up of 'm' number of turns. It carries a current of 5A. If the magnitude of the magnetic field inside the solenoid is 6.28×10^{-3} T, then the value of m is : **[05 April, 2024 (Shift-II)]**

41. A long straight wire of radius a carries a steady current I. The current is uniformly distributed across its cross section. The ratio of the magnetic field at $a/2$ and $2a$ from axis of the wire is: **[08 April, 2024 (Shift-II)]**

(a) 1 : 4 (b) 4 : 1 (c) 1 : 1 (d) 3 : 4

@FAKE_CBSE_X @RAJ_EDUNET

42. Given below are two statements:
Statement (I): When currents vary with time, Newton's third law is valid only if momentum carried by the electromagnetic field is taken into account.
Statement (II): Ampere's circuital law does not depend on Biot-Savart's law.
In the light of the above statements, choose the correct answer from the options given below: **[09 April, 2024 (Shift-I)]**
(a) Both Statement I and Statement II are false.
(b) Statement I is true but Statement II is false.
(c) Statement I is false but Statement II is true.
(d) Both Statement I and Statement II are true.

43. The magnetic intensity at the centre of a long current carrying solenoid is found to be $1.6 \times 10^3\ Am^{-1}$. If the number of turns is 8 per cm, then the current flowing through the solenoid is _____A. **[8 April, 2023 (Shift-I)]**

44. A charge particle moves along circular path in a uniform magnetic field in a cyclotron. The kinetic energy of the charge particle increases to 4 times its initial value. What will be the ratio of new radius to the original radius of circular path of the charge particle: **[29 June, 2022 (Shift-I)]**
(a) 1 : 1 (b) 1 : 2 (c) 2 : 1 (d) 1 : 4

45. A long solenoid carrying a current produces a magnetic field B along its axis. If the current is doubled and the number of turns per cm is halved, the new value of magnetic field will be equal to **[25 June, 2022 (Shift-II)]**
(a) B (b) $2B$ (c) $4B$ (d) $\frac{B}{2}$

46. A long, straight wire of radius a carries a current distributed uniformly over its cross-section. The ratio of the magnetic fields due to the wire at distance $\frac{a}{3}$ and $2a$, respectively from the axis of the wire is **[9 Jan, 2020 (Shift-I)]**
(a) $\frac{1}{2}$ (b) 2 (c) $\frac{3}{2}$ (d) $\frac{2}{3}$

47. A particle having the same charge as of electron moves in a circular path of radius 0.5 cm under the influence of a magnetic field of 0.5 T. If an electric field of 100 V/m makes it to move in a straight path, then the mass of the particle is (given charge of electron $= 1.6 \times 10^{-19}$ C) **[9 Jan, 2019 (Shift-II)]**
(a) $48..1 \times 10^{-31}$ kg (b) 1.6×10^{-27} kg
(c) $49..6 \times 10^{-19}$ kg (d) 2.0×10^{-24} kg

Motion of Charged Particle in Magnetic Field, Magnetic Force

48. A proton moving with a constant velocity passes through a region of space without any change in its velocity. If $\vec{E}$ and $\vec{B}$ represent the electric and magnetic fields respectively, then the region of space may have: **[27 Jan, 2024 (Shift-I)]**
(A) $E = 0, B = 0$ (B) $E = 0, B \neq 0$
(C) $E \neq 0, B = 0$ (D) $E \neq 0, B \neq 0$
Choose the most appropriate answer from the options given below:
(a) (A), (B) and (C) only (b) (A), (C) and (D) only
(c) (A), (B) and (D) only (d) (B), (C) and (D) only

49. Two particles X and Y having equal charges are being accelerated through the same potential difference. Thereafter they enter normally in a region of uniform magnetic field and describes circular paths of radii R_1 and R_2 respectively. The mass ratio of X and Y is: **[29 Jan, 2024 (Shift-II)]**
(a) $\left(\frac{R_2}{R_1}\right)^2$ (b) $\left(\frac{R_1}{R_2}\right)^2$ (c) $\left(\frac{R_1}{R_2}\right)$ (d) $\left(\frac{R_2}{R_1}\right)$

50. A charge of 4.0 μC is moving with a velocity of $4.0 \times 10^6\ ms^{-1}$ along the positive y-axis under a magnetic field $\vec{B}$ of strength $(2\hat{k})$ T. The force acting on the charge is $x\hat{i}$ N. The value of x is _____. **[29 Jan, 2024 (Shift-II)]**

51. An electron moves through a uniform magnetic field $\vec{B} = B_0\hat{i} + 2B_0\hat{j}\ T$. At a particular instant of time, the velocity of electron is $\vec{u} = 3\hat{i} + 5\hat{j}$ m/s. If the magnetic force acting on electron is $\vec{F}$ 5ek N, where e is the charge of electron, then the value of B_0 is _____ T. **[31 Jan, 2024 (Shift-I)]**

52. An electron is projected with uniform velocity along the axis inside a current carrying long solenoid. Then: **[04 April, 2024 (Shift-I)]**
(a) the electron will be accelerated along the axis.
(b) the electron will continue to move with uniform velocity along the axis of the solenoid.
(c) the electron path will be circular about the axis.
(d) the electron will experience a force at 45° to the axis and execute a helical path.

53. The electrostatic force $(\vec{F}_1)$ and magnetic force $(\vec{F}_2)$ acting on a charge q moving with velocity v can be written: **[05 April, 2024 (Shift-II)]**
(a) $\vec{F}_1 = q\vec{V}\cdot\vec{E},\ \vec{F}_2 = q(\vec{B}\cdot\vec{V})$
(b) $\vec{F}_1 = q\vec{B},\ \vec{F}_2 = q(\vec{B}\times\vec{V})$
(c) $\vec{F}_1 = q\vec{E},\ \vec{F}_2 = q(\vec{V}\times\vec{B})$
(d) $\vec{F}_1 = q\vec{E},\ \vec{F}_2 = q(\vec{B}\times\vec{V})$

54. An electron with kinetic energy 5 eV enters a region of uniform magnetic field of 3 μT perpendicular to its direction. An electric field E is applied perpendicular to the direction of velocity and magnetic field. The value of E, so that electron moves along the same path, is_____ NC^{-1}.
(Given, mass of electron $= 9 \times 10^{-31}$ kg, electric charge $= 1.6 \times 10^{-19}$C) **[08 April, 2024 (Shift-I)]**

55. A proton and a deutron ($q = +e$, $m = 2.0u$) having same kinetic energies enter a region of uniform magnetic field $\vec{B}$, moving perpendicular to $\vec{B}$. The ratio of the radius r_d of deutron path to the radius r_p of the proton path is: **[09 April, 2024 (Shift-II)]**
(a) 1 : 1 (b) $1 : \sqrt{2}$ (c) $\sqrt{2} : 1$ (d) 1 : 2

56. A charge particle moving in magnetic field B, has the components of velocity along B as well as perpendicular to B. The path of the charge particle will be **[8 April, 2023 (Shift-I)]**
(a) helical path with the axis perpendicular to the direction of magnetic field B
(b) straight along the direction of magnetic field B

@RAKESH CBSE X @RAJEEBUNEP

(c) helical path with the axis along magnetic field B
(d) circular path

57. An electron is moving along the positive x-axis. If the uniform magnetic field is applied parallel to the negative z-axis, then
A. The electron will experience magnetic force along positive y-axis
B. The electron will experience magnetic force along negative y-axis
C. The electron will not experience any force in magnetic field
D. The electron will continue to move along the positive x-axis
E. The electron will move along circular path in magnetic field
Choose the correct answer from the options given below:
[13 April, 2023 (Shift-II)]

(a) B and E only (b) A and E only
(c) C and D only (d) B and D only

58. An electron is allowed to move with constant velocity along the axis of current carrying straight solenoid.
A. The electron will experience magnetic force along the axis of the solenoid.
B. The electron will not experience magnetic force.
C. The electron will continue to move along the axis of the solenoid.
D. The electron will be accelerated along the axis of the solenoid.
E. The electron will follow parabolic path-inside the solenoid.
Choose the correct answer from the options given below:
[11 April, 2023 (Shift-II)]

(a) B, C and D only (b) B and C only
(c) A and D only (d) B and E only

59. A charge particle of 2 μC accelerated by a potential difference of 100 V enters a region of uniform magnetic field of magnitude 4 mT at right angle to the direction of field. The charge particle completes semicircle of radius 3 cm inside magnetic field. The mass of the charge particle is ____ $\times 10^{-18}$ kg. **[1 Feb, 2023 (Shift-I)]**

60. A proton with a kinetic energy of 2.0 eV moves into a region of uniform magnetic field of magnitude $\frac{\pi}{2}\times10^{-3}\,T$. The angle between the direction of magnetic field and velocity of proton is 60° The pitch of the helical path taken by the proton is ____ cm.
(Take, mass of proton = 1.6×10^{-27} kg and Charge on proton = 1.6×10^{-19} C).
[6 April, 2023 (Shift-II)]

61. Given below are two statements: One is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**.
Assertion (A): In an uniform magnetic field, speed and energy remains the same for a moving charged particle.
Reason (R): Moving charged particle experiences magnetic force perpendicular to its direction of motion. **[24 June, 2022 (Shift-I)]**

(a) Both (A) and (R) are true and (R) is the correct explanation of (A).
(b) Both (A) and (R) are true but (R) is NOT the correct explanation of (A).
(c) (A) is true but (R) is false.
(d) (A) is false but (R) is true.

62. A charge particle is moving in a uniform magnetic field $(2\hat{i}+3\hat{j})$T. If it has an acceleration of $(\alpha\hat{i}-4\hat{j})$m/s^2, then the value of α is
[26 July, 2022 (Shift-I)]

(a) 3 (b) 6 (c) 12 (d) 2

63. A proton, a deuteron and an α- particle with same kinetic energy enter into a uniform magnetic field at right angle to magnetic field. The ratio of the radii of their respective circular paths is:
[24 June, 2022 (Shift-II)]

(a) $1:\sqrt{2}:\sqrt{2}$ (b) $1:1:\sqrt{2}$ (c) $\sqrt{2}:1:1$ (d) $1:\sqrt{2}:1$

64. Two charged particles, having same kinetic energy, are allowed to pass through a uniform magnetic field perpendicular to the direction of motion. If the ratio of radii of their circular paths is 6 : 5 and their respective masses ratio is 9 : 4, then, the ratio of their charges will be
[25 July, 2022 (Shift-I)]

(a) 8 : 5 (b) 5 : 4 (c) 5 : 3 (d) 8 : 7

65. An electron with energy 0.1 keV moves at right angle to the earth's magnetic field of 1×10^{-4} Wbm^{-2}. The frequency of revolution of the electron will be
(Take mass of electron = 9.0×10^{-31} kg) **[25 July, 2022 (Shift-II)]**

(a) $66..6\times10^{5}$ Hz (b) 5.6×10^{5} Hz
(c) $67..8\times10^{6}$ Hz (d) 1.8×10^{6} Hz

66. A proton and an alpha particle of the same velocity enter in a uniform magnetic field which is acting perpendicular to their direction of motion. The ratio of the radii of the circular paths described by the alpha particle and proton is: **[26 June, 2022 (Shift-I)]**

(a) 1 : 4 (b) 4 : 1 (c) 2 : 1 (d) 1 : 2

67. Given below are two statements:
Statement-I: The electric force changes the speed of the charged particle and hence charges its kinetic energy; whereas the magnetic force does not change the kinetic energy of the charged particle.
Statement-II: The electric force accelerates the positively charged particle perpendicular to the direction of electric field. The magnetic force accelerates the moving charged particle along the direction of magnetic field.
In the light of the above statements, choose the most appropriate answer from the options given below: **[29 June, 2022 (Shift-II)]**

(a) Both Statement-I and Statement-II are correct.
(b) Both Statement-I and Statement-II are incorrect.
(c) Statement-I is correct but Statement-II is incorrect.
(d) Statement-I is incorrect but Statement-II is correct.

68. A beam of light travelling along X-axis is described by the electric field $E_y = 900\sin\omega(t-x/c)$. The ratio of electric force to magnetic force on a charge q moving along Y-axis with a speed of 3×10^{7} ms^{-1} will be:
(Given speed of light = 3×10^{8} ms^{-1} **[27 July, 2022 (Shift-I)]**

(a) 1 : 1 (b) 1 : 10 (c) 10 : 1 (d) 1 : 2

69. A velocity selector consists of electric field $\vec{E}=E\hat{k}$ and magnetic field $\vec{B}=B\hat{j}$ with B = 12 mT. The value of E required for and electron of energy 728 eV moving along the positive x-axis to pass undeflected is: **[26 July, 2022 (Shift-II)]**
(Given. Mass of electron = 9.1×10^{-31}kg)

(a) 192 kVm^{-1} (b) 192 mVm^{-1}
(c) 9600 kVm^{-1} (b) 16 kVm^{-1}

70. A 1 m long copper wire carries a current of 1A. If the cross section of the wire is 2.0 mm^2 and the resistivity of copper is 1.7×10^{-8} Ωm,, the force experienced by moving electron in the wire is _____ $\times10^{-23}$ N.
(charge on electorn = -1.6×10^{-19} C) **[27 July, 2022 (Shift-I)]**

@FREE JEE X 10 KNOWLEDUNET

71. A deuteron and a proton moving with equal kinetic energy enter into a uniform magnetic field at right angle to the field. If r_d and r_p are the radii of their circular paths respectively, then the ratio $\frac{r_d}{r_p}$ will be $\sqrt{x}:1$ where x is..... **[27 June, 2022 (Shift-II)]**

72. A singly ionized magnesium atom ($A = 24$) ion is accelerated to kinetic energy 5 ke V, and is projected perpendicularly into a magnetic field B of the magnitude 0.5 T. The radius of path formed will be _____ cm. **[28 June, 2022 (Shift-I)]**

73. A deuteron and an alpha particle having equal kinetic energy enter perpendicularly into a magnetic field. Let r_d and $r\alpha$ be their respective radii of circular path. The value of $\frac{r_d}{r_\alpha}$ is equal to: **[20 July, 2021 (Shift-I)]**

(a) $\sqrt{2}$ (b) 2 (c) $\frac{1}{\sqrt{2}}$ (d) 1

74. A proton and an α-particle, having kinetic energy K_p and $K\alpha$ respectively, enter into a magnetic field at right angles. The ratio of the radii of trajectory of proton to that of α-particle is 2 : 1. The ratio of $K_p : K\alpha$ is **[18 March, 2021 (Shift-II)]**

(a) 1 : 8 (b) 8 : 1 (c) 1 : 4 (d) 4 : 1

75. Two ions of masses 4 amu and 16 amu have charges + 2e and + 3e respectively. These ions pass through the region of constant perpendicular magnetic field. The kinetic energy of both ions is same. Then: **[27 Aug, 2021 (Shift-I)]**

(a) No ion will be deflected.
(b) Both ions will be deflected equally
(c) Lighter ion will be deflected more than heavier ion
(d) Lighter ion will be deflected less than heavier ion

76. A charge Q is moving $d\vec{\ell}$ distance in the magnetic field $\vec{B}$.. Find the value of work done by $\vec{B}$. **[16 March, 2021 (Shift-II)]**

(a) 1 (b) Zero (c) Infinite (d) −1

77. Two ions having same mass have charges in the ratio 1 : 2. They are projected normally in a uniform magnetic field with their speeds in the ratio 2 : 3. The ratio of the radii of their circular trajectories is: **[25 July, 2021 (Shift-II)]**

(a) 3 : 1 (b) 2 : 3 (c) 4 : 3 (d) 1 : 4

78. A proton, a deuteron and an α-particle are moving with same momentum in a uniform magnetic field. The ratio of magnetic forces acting on them is _____ and their speed is _____, in the ratio. **[25 Feb, 2021 (Shift-I)]**

(a) 4 : 2 : 1 and 2 : 1 : 1 (b) 2 : 1 : 1 and 4 : 2 : 1
(c) 1 : 2 : 4 and 1 : 1 : 2 (d) 1 : 2 : 4 and 2 : 1 : 1

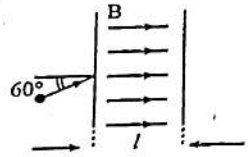
79. A particle of mass m and charge q has an initial velocity $\vec{v} = v_0\hat{j}$. If an electric field $\vec{E} = E_0\hat{i}$ and magnetic field $\vec{B} = B_0\hat{i}$ act on the particle, its speed will double after a time **[7 Jan, 2020 (Shift-II)]**

(a) $\frac{2mv_0}{qE_0}$ (b) $\frac{3mv_0}{qE_0}$ (c) $\frac{\sqrt{2}mv_0}{qE_0}$ (d) $\frac{\sqrt{3}mv_0}{qE_0}$

80. An electron is moving along +x direction with a velocity of $6\times10^6\ ms^{-1}$. It enters a region of uniform electric field of 300 V/cm pointing along +y direction. The magnitude and direction of the magnetic field set up in this region such that the electron keeps moving along the x direction will be: **[6 Sep, 2020 (Shift-I)]**

(a) 3×10^{-4} T, along +z direction
(b) 5×10^{-3} T, along −z direction
(c) 5×10^{-3} T, along +z direction
(d) 3×10^{-4} T, along −z direction

81. The figure shows a region of length 'ℓ' with a uniform magnetic field of 0.3 T in it and a proton entering the region with velocity $4 \times 10^5\ ms^{-1}$ making an angle 60° with the field. If the proton completes 10 revolution by the time it cross the region shown, 'ℓ' is close to (mass of proton = 1.67×10^{-27} kg, charge of the proton = 1.6×10^{-19} C) **[2 Sep, 2020 (Shift-II)]**



(a) 0.44 m (b) 0.11 m (c) 0.88 m (d) 0.22 m

82. A charged particle carrying charge 1 μC is moving with velocity $(2\hat{i}+3\hat{j}+4\hat{k})ms^{-1}$. If an external magnetic field of $(5\hat{i}+3\hat{j}-6\hat{k})\times10^{-3}$T exists in the region where the particle is moving then the force on the particle is $\vec{F}\times10^{-9}$N. The vector $\vec{F}$ is **[3 Sep, 2020 (Shift-I)]**

(a) $-3.0\hat{i}+3.2\hat{j}-0.9\hat{k}$ (b) $-300\hat{i}+320\hat{j}-90\hat{k}$
(c) $-0.30\hat{i}+0.32\hat{j}-0.09\hat{k}$ (d) $-30\hat{i}+32\hat{j}-9\hat{k}$

83. A particle of charge q and mass m is moving with a velocity $-vi(v\neq0)$ towards a large screen placed in the $Y-Z$ plane at a distance d. If there is a magnetic field $\vec{B} = B_0\,k$, the minimum value of v for which the particle will not hit the screen is: **[6 Sep, 2020 (Shift-I)]**

(a) $\frac{qdB_0}{3m}$ (b) $\frac{2qdB_0}{m}$ (c) $\frac{qdB_0}{m}$ (d) $\frac{qdB_0}{2m}$

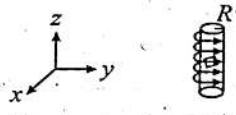
84. Proton with kinetic energy of 1 MeV moves from south to north. It gets an acceleration of $10^{12}m/s^2$ by an applied magnetic field (west to east). The value of magnetic field. (Rest mass of proton is 1.6×10^{-27} kg) **[8 Jan, 2020 (Shift-I)]**

(a) 85...1 mT (b) 71 mT (c) 0.71 mT (d) 0.071 mT

85. A beam of protons with speed 4×10^5 m/s enters a uniform magnetic field of 0.3 T at an angle of 60° to the magnetic field. The pitch of the resulting helical path of protons is close to (Mass of the proton = 1.67×10^{-27} kg, charge of the proton = 1.69×10^{-19} C) **[2 Sep, 2020 (Shift-I)]**

(a) 2 cm (b) 12 cm (c) 5 cm (d) 4 cm

86. An electron gun is placed inside a long solenoid of radius R on its axis. The solenoid has n turns/length and carries a current I. The electron gun shoots an electron along the radius of the solenoid with speed v. If the electron does not hit the surface of the solenoid, maximum possible value of v is (all symbols have their standard meaning) **[9 Jan, 2020 (Shift-II)]**

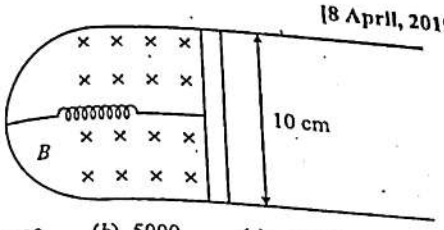


(a) $\frac{e\mu_0 nIR}{2m}$ (b) $\frac{e\mu_0 nIR}{m}$ (c) $\frac{2e\mu_0 nIR}{m}$ (d) $\frac{e\mu_0 nIR}{4m}$

@TAKE_CARE_X @RAJEDUNET

87. A thin strip 10 cm long is on a U shaped wire of negligible resistance and it is connected to a spring of spring constants 0.5 Nm^{-1} (see figure). The assembly is kept in a uniform magnetic field of 0.1 T. If the strip is pulled from its equilibrium position and released, the number of oscillation it performs before its amplitude decreases by a factor of e is N. If the mass of the strip is 50 grams, its resistance 10 Ω and air drag negligible, N will be close to

[8 April, 2019 (Shift-I)]



(a) 50000 (b) 5000 (c) 10000 (d) 1000

88. A moving coil galvanometer has a coil with 175 turns and area 1 cm^2. It uses a torsion band of torsion constant 10^{-6} N–m/rad. The coil is placed in a magnetic field B parallel to its plane. The coil deflects by 1° for a current of 1 mA. The value of B (in Tesla) is approximately **[9 April, 2019 (Shift-II)]**

(a) 10^{-3} (b) 10^{-1} (c) 10^{-4} (d) 10^{-2}

89. A proton, an electron, and a Helium nucleus, have the same energy. They are in circular orbitals in a plane due to magnetic field perpendicular to the plane. Let r_p, r_e and r_{He} be their respective radii, then, **[10 April, 2019 (Shift-I)]**

(a) $r_e > r_p > r_{He}$ (b) $r_e < r_p < r_{He}$

(c) $r_e < r_p = r_{He}$ (d) $r_e > r_p = r_{He}$

90. The region between y = 0 and y = d contains a magnetic field $\vec{B} = B\hat{z}$. A particle of mass m and charge q enters the region with a velocity $\vec{v} = v\hat{i}$. If $d = \frac{mv}{2qB}$, the acceleration of the charged particle at the point of its emergence at the other side is:

[11 Jan, 2019 (Shift-II)]

(a) $\frac{qvB}{m}\left(\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j}\right)$ (b) $\frac{qvB}{m}\left(\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right)$

(c) $\frac{qvB}{m}\left(\frac{-\hat{j}+\hat{i}}{\sqrt{2}}\right)$ (d) $\frac{qvB}{m}\left(\frac{\hat{j}+\hat{i}}{\sqrt{2}}\right)$

91. A proton and an α-particle (with their masses in the ratio of 1 : 4 and charges in the ratio of 1 : 2) are accelerated from rest through a potential difference V. If a uniform magnetic field (B) is set up perpendicular to their velocities, the ratio of the radii $r_p : r\alpha$ of the circular paths described by them will be **[12 Jan, 2019 (Shift-I)]**

(a) $1:\sqrt{2}$ (b) 1 : 2 (c) 1 : 3 (d) $1:\sqrt{3}$

92. In an experiment, electrons are accelerated, from rest, by applying, a voltage of 500 V. Calculate the radius of the path if a magnetic field 100 mT is then applied. [Charge of the electron = 1.6×10^{-19} C Mass of the electron = 9.1×10^{-31} kg] **[11 Jan, 2019 (Shift-I)]**

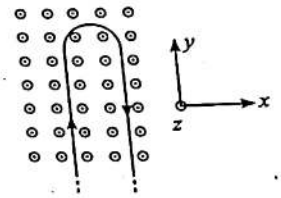
(a) 93..5 × 10^{-3} m (b) 7.5 × 10^{-2} m

(c) 94..5 m (d) 7.5 × 10^{-4} m

Magnetic Force on Current Carrying Wire

93. The horizontal component of earth's magnetic field at a place is 3.5×10^{-5} T. A very long straight conductor carrying current of $\sqrt{2}A$ in the direction from South east to North West is placed. The force per unit length experienced by the conductor is _____ × 10^{-6} N/m. **[30 Jan, 2024 (Shift-I)]**

94. A rigid wire consists of a semicircular portion of radius R and two straight sections. The wire is partially immerged in a perpendicular magnetic field $B = B_0\hat{j}$ as shown in figure. The magnetic force on the wire if it has a current I is: **[31 Jan, 2024 (Shift-I)]**

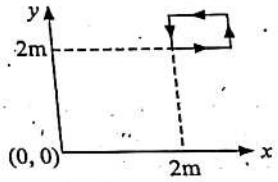


(a) $-iBR\hat{j}$ (b) $2iBR\hat{j}$ (c) $iBR\hat{j}$ (d) $-2iBR\hat{j}$

95. The magnetic field existing in a region is given by $\vec{B} = 0.2(1 + 2x)\hat{k}T$.

A square loop of edge 50 cm carrying 0.5 A current is placed in x-y plane with its edges parallel to the x-y axes, as shown in figure. The magnitude of the net magnetic force experienced by the loop is _____ mN.

[04 April, 2024 (Shift-I)]



96. A 2A current carrying straight metal wire of resistance 1 Ω, resistivity 2 × 10^{-6} Ωm, area of cross-section 10 mm^2 and mass 500 g is suspended horizontally in mid air by applying a uniform magnetic field B. The magnitude of B is ..... × 10^{-1} T (given, g = 10 m/s^2). **[05 April, 2024 (Shift-I)]**

97. A square loop of edge length 2 m carrying current of 2 A is placed with its edges parallel to the x-y axis. A magnetic field is passing through the x-y plane and expressed as $\vec{B} = B_0(1 + 4x)\hat{k}$, where B_0 = 5 T. The net magnetic force experienced by the loop is _____ N. **[09 April, 2024 (Shift-I)]**

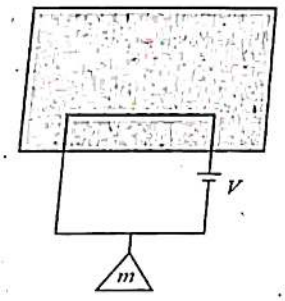
98. Two long straight wires P and Q carrying equal current of 10A each were kept parallel to each other at a distance of 5cm. Magnitude of magnetic force experienced by 10cm length of wire P is F_1. If distance between the wires is halved and currents on them are doubled, force F_2 on 10 cm length of wire P will be: **[24 Jan, 2023 (Shift-I)]**

(a) $8F_1$ (b) $10F_1$ (c) $F_1/8$ (d) $F_1/10$

@FAKE CBSE X @RAJEDUNET

99. A massless square loop, of wire of resistance 10Ω, supporting a mass of 1 g, hangs vertically with one of its sides in a uniform magnetic field of $10^3 G$, directed outwards in the shaded region. A dc voltage V is applied to the loop. For what value of V, the magnetic force will exactly balance the weight of the supporting mass of 1 g?

(If sides of the loop $= 10\,cm, g = 10\,ms^{-2}$) **[30 Jan, 2023 (Shift-I)]**

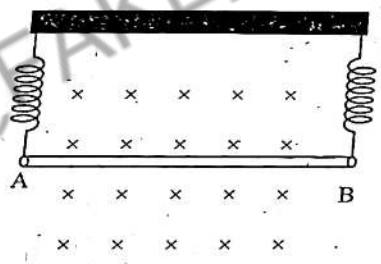


(a) $\frac{1}{10}$ V (b) 100 V (c) 1 V (d) 10 V

100. A current carrying rectangular loop PQRS is made of uniform wire. The length PR = QS = 5cm and PR = QS = 100 cm. If ammeter current reading changes from I to 2I, the ratio of magnetic forces per unit length on the wire PQ due to wire RS in the two cases respectively, $f^{I}_{PQ} : f^{2I}_{PQ}$ is: **[30 Jan, 2023 (Shift-II)]**

(a) 1 : 2 (b) 1 : 4 (c) 1 : 5 (d) 1 : 3

101. A straight wire *AB* of mass 40 *g* and length 50 cm is suspended by a pair of flexible leads in uniform magnetic field of magnitude 0.40 *T* as shown in the figure. The magnitude of the current required in the wire to remove the tension in the supporting leads is _____ A. (Take $g = 10\ ms^{-2}$). **[13 April, 2023 (Shift-II)]**



102. A particle of mass *m* and charge *q* is in an electric and magnetic field given by:

$\vec{E} = 2\hat{i} + 3\hat{j}\,;\ B = 4\hat{j} + 6\hat{k}$

The charged particle is shifted from the origin to the point $P(x = 1;\ y = 1)$ along a straight path. The magnitude of the total work done is: **[11 Jan, 2019 (Shift-II)]**

(a) (0.35)*q* (b) 5*q* (c) (2.5)*q* (d) (0.15)*q*

Torque and Potential Energy of Coil in External Magnetic Field, Current Sensitivity

103. A current of 200 μA deflects the coil of a moving coil galvanometer through 60°. The current to cause deflection through $\frac{\pi}{10}$ radian is: **[27 Jan, 2024 (Shift-II)]**

(a) 30 μA (b) 120 μA (c) 60 μA (d) 180 μA

104. The deflection in moving coil galvanometer falls from 25 divisions to 5 division when a shunt of 24Ω is applied. The resistance of galvanometer coil will be: **[29 Jan, 2024 (Shift-I)]**

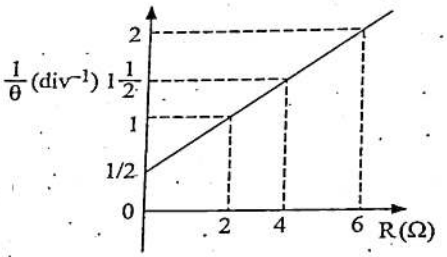
(a) 12Ω (b) 96Ω (c) 48Ω (d) 100Ω

105. A uniform magnetic field of 2×10^{-3}T acts along positive Y-direction. A rectangular loop of sides 20 cm and 10 cm with current of 5 A is Y-Z plane. The current is in anticlockwise sense with reference to negative X axis. Magnitude and direction of the torque is: **[31 Jan, 2024 (Shift-II)]**

(a) 2×10^{-4} N–m along positive Z – direction
(b) 2×10^{-4} N– m along negative Z– direction
(c) 2×10^{-4} N– m along positive X– direction
(d) 2×10^{-4} N– m along positive Y– direction

106. A moving coil galvanometer has 100 turns and each turn has an area of 2.0 cm^2. The magnetic field produced by the magnet is 0.01 *T* and the deflection in the coil is 0.05 radian when a current of 10 mA is passed through it. The torsional constant of the suspension wire is $x \times 10^{-5}$ N–m/rad. The value of *x* is _____. **[1 Feb, 2024 (Shift-II)]**

107. In the experiment to determine the galvanometer resistance by half-deflection method, the plot of 1/θ vs the resistance (*R*) of the resistance box is shown in the figure. The figure of merit of the galvanometer is ..... $\times 10^{-1}$ A/division. [The source has emf 2V] **[05 April, 2024 (Shift-I)]**



108. A circular coil having 200 turns, 2.5×10^{-4} m^2 area and carrying 100 μA current is placed in a uniform magnetic field of 1 *T*. Initially the magnetic dipole moment $(\vec{M})$ was directed along $\vec{B}$. Amount of work, required to rotate the coil through 90° from its initial orientation such that $\vec{M}$ becomes perpendicular to *B*, is _____ μJ. **[06 April, 2024 (Shift-I)]**

109. A coil having 100 turns, area of 5×10^{-3} m^2, carrying current of 1 mA is placed in uniform magnetic field of 0.20 T such a way that plane of coil is perpendicular to the magnetic field. The work done in turning the coil through 90° is _____μJ. **[06 April, 2024 (Shift-II)]**

@FAKE_CASE X @FREE_NET

110. Certain galvanometers have a fixed core made of non magnetic metallic material. The function of this metallic material is **[8 April, 2023 (Shift-I)]**

(a) to oscillate the coil in magnetic field for longer period of time
(b) to bring the coil to rest quickly
(c) to produce large deflecting torque on the coil
(d) to make the magnetic field radial

111. The current sensitivity of moving coil galvanometer is increased by 25%. This increase is achieved only by changing in the number of turns of coils and area of cross section of the wire while keeping the resistance of galvanometer coil constant. The percentage change in the voltage sensitivity will be: **[11 April, 2023 (Shift-I)]**

(a) +25% (b) −50% (c) Zero (d) −25%

112. Given below are two statement:

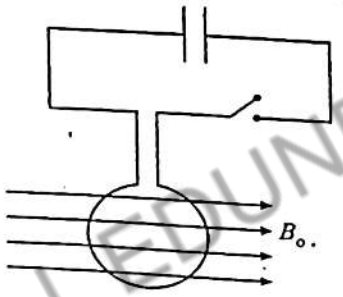
Statement-I : If the number of turns in the coil of a moving coil galvanometer is doubled then the current sensitivity becomes double.

Statement-II : Increasing current sensitivity of a moving coil galvanometer by only increasing the number of turns in the coil will also increase its voltage sensitivity in the same ratio:

In the light of the above statement, choose the correct answer from the options given below: **[10 April, 2023 (Shift-I)]**

(a) Statement-I is false but Statement-II is true
(b) Both Statement-I and Statement-II are true
(c) Both Statement-I and Statement-II are false
(d) Statement-I is true but Statement-II is false

113. A circular coil of radius R and N turns has negligible resistance. As shown in the schematic figure, its two ends are connected to two wires and it is hanging by those wires with its plane being vertical. The wires are connected to a capacitor with charge Q through a switch. The coil is in a horizontal uniform magnetic field B parallel to the plane of the coil. When the switch is closed, the capacitor gets discharged through the coil in a very short time. By the time the capacitor is discharged fully, magnitude of the angular momentum gained by the coil will be (assume that the discharge time is so short that the coil has hardly rotated during this time) **[JEE Adv, 2020]**



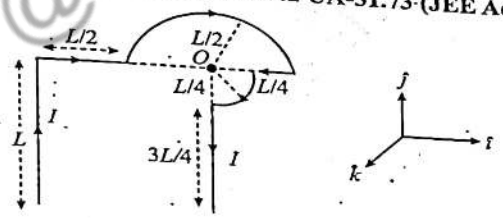
(a) $\frac{\pi}{2}NQB_0R^2$ (b) πNQB_0R^2
(c) $2\pi NQB_0R^2$ (d) $4\pi NQB_0R^2$

JEE-Advanced

Biot Savart Law

Single Correct

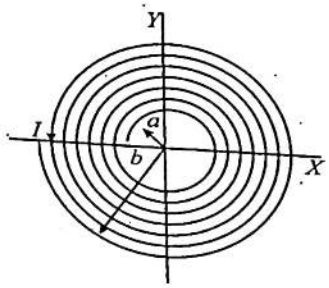
1. Which one of the following options represents the magnetic field $\vec{B}$ at O due to the current flowing in the given wire segments lying on the xy plane? **C-23.85 W-44.42 UA-31.73 (JEE Adv. 2022)**



(a) $\vec{B}=\frac{-\mu_0 I}{L}\left(\frac{3}{2}+\frac{1}{4\sqrt{2}\pi}\right)\hat{k}$ (b) $\vec{B}=-\frac{\mu_0 I}{L}\left(\frac{3}{2}+\frac{1}{2\sqrt{2}\pi}\right)\hat{k}$

(c) $\vec{B}=\frac{-\mu_0 I}{L}\left(1+\frac{1}{4\sqrt{2}\pi}\right)\hat{k}$ (d) $\vec{B}=\frac{-\mu_0 I}{L}\left(1+\frac{1}{4\pi}\right)\hat{k}$.

2. A long insulated copper wire is closely wound as a spiral of N turns. The spiral has inner radius a and outer radius b. The spiral lies in the $X-Y$ plane and a steady current I flows through the wire. The Z-component of the magnetic field at the centre of the spiral is



(IIT-JEE 2011)

(a) $\frac{\mu_0 NI}{2(b-a)}ln\left(\frac{b}{a}\right)$ (b) $\frac{\mu_0 NI}{2(b-a)}ln\left(\frac{b+a}{b-a}\right)$

(c) $\frac{\mu_0 NI}{2b}ln\left(\frac{b}{a}\right)$ (d) $\frac{\mu_0 NI}{2b}ln\left(\frac{b+a}{b-a}\right)$

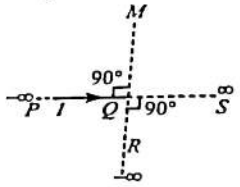
3. A long straight wire along the Z-axis carries a current I in the negative Z–direction. The magnetic vector field B at a point having coordinates (x, y) in the $Z=0$ plane is **(IIT-JEE 2002)**

(a) $\frac{\mu_0 I\left(y\hat{i}-x\hat{j}\right)}{2\pi\left(x^2+y^2\right)}$ (b) $\frac{\mu_0 I\left(x\hat{i}+y\hat{j}\right)}{2\pi\left(x^2+y^2\right)}$

(c) $\frac{\mu_0 I\left(x\hat{j}-y\hat{i}\right)}{2\pi\left(x^2+y^2\right)}$ (d) $\frac{\mu_0 I\left(x\hat{i}-y\hat{j}\right)}{2\pi\left(x^2+y^2\right)}$

@FAKE_CBSE_X @RAJ_EDUNET

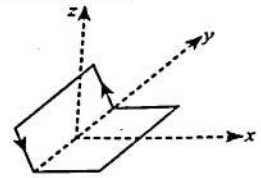
4. An infinitely long conductor PQR is bent to form a right angle as shown in figure. A current I flows through PQR. The magnetic field due to this current at the point M is B_1. Now, another infinitely long straight conductor QS is connected at Q, so that current is $I/2$ in QR as well as in QS, the current in PQ remaining unchanged. The magnetic field at M is now B_2. The ratio B_1/B_2 is given by



(IIT-JEE 2000)

(a) 1/2 (b) 1 (c) 2/3 (d) 2

5. A non-planar loop of conducting wire carrying a current I is placed as shown in the figure. Each of the straight sections of the loop is of length $2a$. The magnetic field due to this loop at the point $P(a, 0, a)$ points in the direction **(IIT-JEE 2001)**



(a) $\frac{1}{\sqrt{2}}\left(-\hat{j}+\hat{k}\right)$ (b) $\frac{1}{\sqrt{3}}\left(-\hat{j}+\hat{k}+\hat{i}\right)$

(c) $\frac{1}{\sqrt{3}}\left(\hat{i}+\hat{j}+\hat{k}\right)$ (d) $\frac{1}{\sqrt{2}}\left(\hat{i}+\hat{k}\right)$

6. A battery is connected between two points A and B on the circumference of a uniform conducting ring of radius r and resistance R. One of the *arcs* AB of the ring subtends an angle θ at the center. The value of the magnetic induction at the center due to the current in the ring is **(IIT-JEE 1995)**

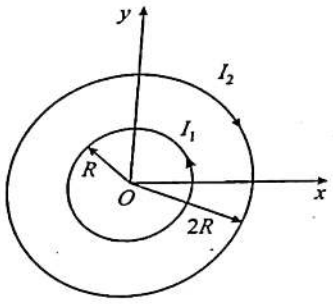
(a) Proportional to $(180° - \theta)$ (b) Inversely proportional to r

(c) Zero, only if $(\theta = 180°)$ (d) Zero for all values of θ

Multiple Correct

7. Two concentric circular loops, one of radius R and the other of radius $2R$, lie in the xy-plane with the origin as their common center, as shown in the figure. The smaller loop carries current I_1 in the anti-clockwise direction and the larger loop carries current I_2 in the clockwise direction, with $I_2 > 2I_1$. $\vec{B}(x, y)$ denotes the magnetic field at a point (x, y) in the xy-plane. Which of the following statement(s) is/are correct?

C-7.77 W-43.5 UA-30.62 PC-18.12 (JEE Adv. 2021)



(a) $\vec{B}(x, y)$ is perpendicular to the xy-plane at any point in the plane.

(b) $\left|\vec{B}(x, y)\right|$ depends on x and y only through the radial distance $r = \sqrt{x^2 + y^2}$.

(c) $\left|\vec{B}(x, y)\right|$ is non-zero at all points for $r < R$.

(d) $\vec{B}(x, y)$ points normally outward from the plane for all the points between the two loops.

8. Two infinitely long straight wires lie in the xy-plane along the lines $x = \pm R$. The wire located at $x = +R$ carries a constant current I_1 and the wire located at $x = -R$ carries a constant current I_2. A circular loop of radius R is suspended with its center at $\left(0, 0, \sqrt{3}R\right)$ and in a plane parallel to the xy-plane. This loop carries a constant current I in the clockwise direction as seen from above the loop. The current in the wire is taken to be positive, if it is in the $+\hat{j}$ -direction. Which of the following statements regarding the magnetic field B is/are true? **C-8.69 W-19.28 UA-33.97 PC-38.06 (JEE Adv. 2018)**

(a) If $I_1 = I_2$, then B cannot be equal to zero at the origin $(0, 0, 0)$

(b) If $I_1 > 0$ and $I_2 < 0$, then B can be equal to zero at the origin $(0, 0, 0)$

(c) If $I_1 < 0$ and $I_2 > 0$, then B can be equal to zero at the origin $(0, 0, 0)$

(d) If $I_1 = I_2$, then the z-component of the magnetic field at the center of the loop is $\left(-\frac{\mu_0 I}{2R}\right)$

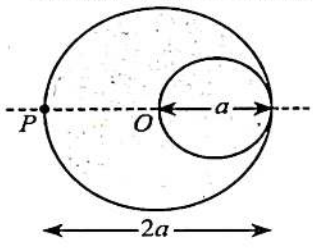
Numerical Types/Integer Types

9. Two parallel wires in the plane of the paper are distance x_0 apart. A point charge is moving with speed u between the wires in the same plane at a distance x_1 from one of the wires, When the wires carry current of magnitude I in the same direction, the radius of curvature of the path of the point charge is R_1. In contrast, if the currents I in the two wires have directions opposite to each other, the radius of curvature of the path is R_2. If $\frac{x_0}{x_1} = 3$, and value of $\frac{R_1}{R_2}$ is

C-41.5 W-50.31 UA-8.18 (JEE Adv. 2014)

10. A cylindrical cavity of diameter a exists inside a cylinder of diameter $2a$ as shown in the figure. Both the cylinder and the cavity are infinitely long. A uniform current density J flows along the length. If the magnitude of the magnetic field at the point P is given by $\frac{N}{12}\mu_0 a.J$, then the value of N is

C-10.26 W-74.02 UA-15.72 (IIT-JEE 2012)

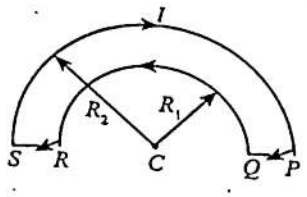


@RAJ_CBSE_EDUNET

11. A steady current I goes through a wire loop PQR having shape of a right angle triangle with $PQ = 3x$, $PR = 4x$ and $QR = 5x$. If the magnitude of the magnetic field at P due to this loop is $k\left(\frac{\mu_0 I}{48\pi x}\right)$, find the value of k **(IIT-JEE 2009)**

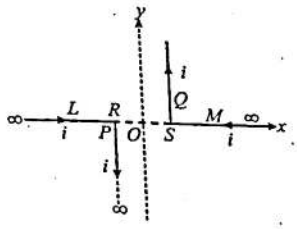
Fill in the Blanks

12. The wire loop $PQRSP$ formed by joining two semicircular wires of radii R_1 and R_2 carries a current I as shown. The magnitude of the magnetic induction at the centre C is ..... **(IIT-JEE 1988)**



Subjective

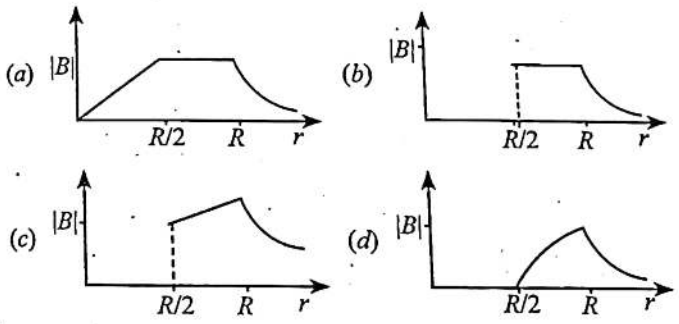
13. A pair of stationary and infinitely long bent wires are placed in the xy plane as shown in figure. The wires carry current of $i = 10$ A each as shown. The segments L and M are along the x-axis. The segments P and Q are parallel to the y-axis such that $OS = OR = 0.02$m. Find the magnitude and direction of the magnetic induction at the origin O. **(IIT-JEE 1989)**



Ampere's Law and Its Application

Single Correct

14. An infinitely long hollow conducting cylinder with inner radius $R/2$ and outer radius R carries a uniform current density along its length. The magnitude of the magnetic field, $|B|$ as a function of the radial distance r from the axis is best represented by **(IIT-JEE 2012)**



Motion of Charged Particle in Magnetic Field

Single Correct

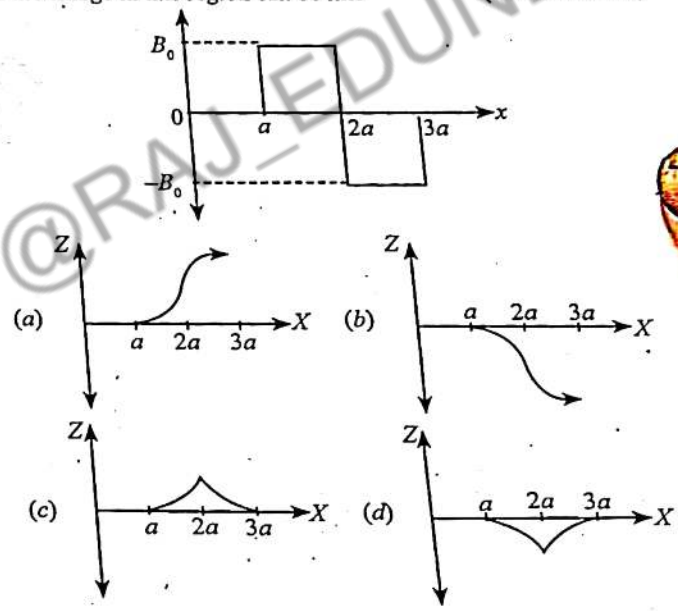
15. A particle of mass m and charge q moves with a constant velocity v along the positive x-direction. It enters a region containing a uniform magnetic field B directed along the negative z-direction, extending from $x = a$ to $x = b$. The minimum value of v required so that the particle can just enter the region $x > b$ is **(IIT-JEE 2002)**

(a) $\frac{qbB}{m}$ (b) $\frac{q(b-a)B}{m}$ (c) $\frac{qaB}{m}$ (d) $\frac{q(b+a)B}{2m}$

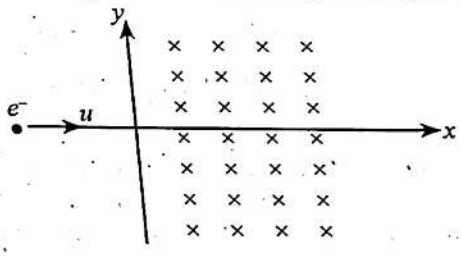
16. A charged particle is released from rest in a region of steady and uniform electric and magnetic fields which are parallel to each other. The particle will move in a **(IIT-JEE 1999)**

(a) Straight line (b) Circle (c) Helix (d) Cycloid

17. A magnetic field $B = B_0\hat{j}$ exists in the region $a < x < 2a$ and $B = -B_0\hat{j}$, in the region $2a < x < 3a$, where B_0 is a positive constant. A positive point charge moving with a velocity $v = v_0\hat{i}$, where v_0 is a positive constant, enters the magnetic field at $x = a$. The trajectory of the charge in this region can be like **(IIT-JEE 2007)**



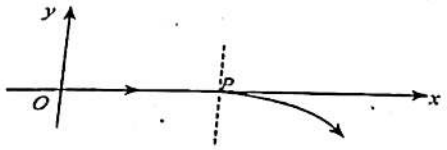
18. An electron moving with a speed u along the positive x-axis at $y = 0$ enters a region of uniform magnetic field $B = -B_0\hat{k}$ which exists to the right of y-axis. The electron exits from the region after some time with the speed v at coordinate y, then **(IIT-JEE 2004)**



(a) $v > u, y < 0$ (b) $v = u, y > 0$ (c) $v > u, y > 0$ (d) $v = u, y < 0$

@FAKE_CBSE_X @RAJ_EDUNET

19. For a positively charged particle moving in a $x-y$ plane initially along the x-axis, there is a sudden change in its path due to the presence of electric and/or magnetic fields beyond P. The curved path is shown in the $x-y$ plane and is found to be non-circular) Which one of the following combinations is possible? **(IIT-JEE 2003)**



(a) $E = 0; B = b\hat{j} + c\hat{k}$ (b) $E = a\hat{i}; B = c\hat{k} + a\hat{i}$

(c) $E = 0; B = c\hat{j} + b\hat{k}$ (d) $E = a\hat{i}; B = c\hat{k} + b\hat{j}$

20. An ionized gas contains both positive and negative ions. If it is subjected simultaneously to an electric field along the $+x$-direction and a magnetic field along the $+z$-direction, then **(IIT-JEE 2000)**

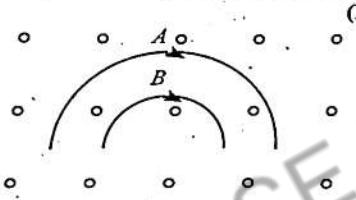
(a) Positive ions deflect towards $+y$-direction and negative ions towards $-y$-direction

(b) All ions deflect towards $+y$-direction

(c) All ions deflect towards $-y$-direction

(d) Positive ions deflect towards $-y$-direction and negative ions towards $+y$-direction

21. Two particles A and B of masses m_A and m_B respectively and having the same charge are moving in a plane. A uniform magnetic field exists perpendicular to this plane. The speeds of the particles are v_A and v_B, respectively and the trajectories are as shown in the figure. Then **(IIT-JEE 2001)**



(a) $m_A v_A < m_B v_B$ (b) $m_A v_A > m_B v_B$

(c) $m_A < m_B$ and $v_A < v_B$ (d) $m_A = m_B$ and $v_A = v_B$

22. A proton, a deutron and an α-particle having the same kinetic energy are moving in circular trajectories in a constant magnetic field. If r_p, r_d and r_α denote, respectively the radii of the trajectories of these particles, then **(IIT-JEE 1997)**

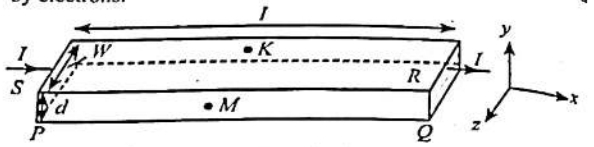
(a) $r_\alpha = r_p < r_d$ (b) $r_\alpha > r_d > r_p$ (c) $r_\alpha = r_d < r_p$ (d) $r_p = r_d < r_\alpha$

23. Two particles X and Y having equal charges, after being accelerated through the same potential difference, enter a region of uniform magnetic field and describe circular paths of radii R_1 and R_2 respectively. The ratio of the mass of X to that of Y is **(IIT-JEE 1988)**

(a) $(R_1/R_2)^{1/2}$ (b) R_2/R_1 (c) $(R_1/R_2)^2$ (d) R_1/R_2

Multiple Correct

24. In a thin rectangular metallic strip a constant current I flows along the positive x-direction, as shown in the figure. The length, width and thickness of the strip are l, w and d, respectively. A uniform magnetic field B is applied on the strip along the positive y-direction. Due to this, the charge carriers experience a net deflection along the z-direction. This results in accumulation of charge carriers on the surface $PQRS$ and appearance of equal and opposite charges on the face opposite to $PQRS$. A potential difference along the z-direction is thus developed. Charge accumulation continues until the magnetic force is balanced by the electric force. The current is assumed to be uniformly distributed on the cross section of the strip and carried by electrons.



Consider two different metallic strips (1 and 2) of the same material. Their lengths are the same, widths are w_1 and w_2 and thicknesses are d_1 and d_2, respectively. Two points K and M are symmetrically located on the opposite faces parallel to the $x-y$ plane (see figure). V_1 and V_2 are the potential differences between K and M in strips 1 and 2 , respectively. Then, for a given current I flowing through them in a given magnetic field strength B, the correct statements is/are **(JEE Adv. 2015)**

(a) If $w_1 = w_2$ and $d_1 = 2d_2$, then $V_2 = 2V_1$

(b) If $w_1 = w_2$ and $d_1 = 2d_2$, then $V_2 = V_1$

(c) If $w_1 = 2w_2$ and $d_1 = d_2$, then $V_2 = 2V_1$

(d) If $w_1 = 2w_2$ and $d_1 = d_2$, then $V_2 = V_1$

25. A particle of mass M and positive charge Q, moving with a constant velocity $u_1 = 4\hat{i}\ \text{ms}^{-1}$, enters a region of uniform static magnetic field normal to the $x-y$ plane. The region of the magnetic field extends from $x = 0$ to $x = L$ for all values of y. After passing through this region, the particle emerges on the other side after 10 milliseconds with a velocity $u_2 = 2\left(\sqrt{3}\hat{i} + \hat{j}\right)\text{ms}^{-1}$. The correct statement(s) is/are **(JEE Adv. 2013)**

(a) The direction of the magnetic field is $-z$ direction.

(b) The direction of the magnetic field is $+z$ direction

(c) The magnitude of the magnetic field is $\frac{50\pi M}{3Q}$ units

(d) The magnitude of the magnetic field is $\frac{100\pi M}{3Q}$ units

26. An electron and a proton are moving on straight parallel paths with same velocity. They enter a semi-infinite region of uniform magnetic field perpendicular to the velocity. Which of the following statement(s) is/are true? **(IIT-JEE 2011)**

(a) They will never come out of the magnetic field region

(b) They will come out travelling along parallel paths

(c) They will come out at the same time

(d) They will come out at different times

27. Consider the motion of a positive point charge in a region where there are simultaneous uniform electric and magnetic fields $E = E_0\hat{j}$ and $B = B_0\hat{j}$. At time $t = 0$, this charge has velocity v in the $x-y$ plane, making an angle θ with the x-axis. Which of the following option(s) is/are correct for time $t > 0$?

C-9.64 W-81.69 UA-8.67 (IIT-JEE 2012)

@FAKE_CBSE X @RAY EDUCATE

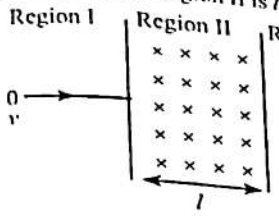
(a) If $\theta = 0°$, the charge moves in a circular path in the $x-z$ plane

(b) If $\theta = 0°$, the charge undergoes helical motion with constant pitch along the y-axis

(c) If $\theta = 10°$, the charge undergoes helical motion with its pitch increasing with time, along the y-axis

(d) If $\theta = 90°$, the charge undergoes linear but accelerated motion along the y-axis

28. A particle of mass m and charge q, moving with velocity v enters Region II normal to the boundary as shown in the figure. Region II has a uniform magnetic field B perpendicular to the plane of the paper. The length of the Region II is l. Choose the correct choice (s)



(IIT-JEE 2008)

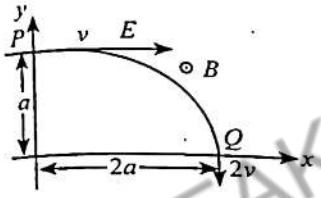
(a) The particle enters Region III only if its velocity $v > \frac{qlB}{m}$

(b) The particle enters Region III only if its Velocity $v < \frac{qlB}{m}$

(c) Path length of the particle in Region II is maximum when velocity $v = qlB/m$

(d) Time spent in Region II is same for any velocity v as long as the particle returns to Region I

29. A particle of charge $+q$ and mass m moving under the influence of a uniform electric field $E\hat{i}$ and uniform magnetic field $B\hat{k}$ follows a trajectory from P to Q as shown in figure. The velocities at P and Q are $v\hat{i}$ and $-2v\hat{j}$. Which of the following statement(s) is/are correct?



(IIT-JEE 1991)

(a) $E = \frac{3}{4}\left[\frac{mv^2}{qa}\right]$

(b) Rate of work done by the electric field at P is $\frac{3}{4}\left[\frac{mv^3}{a}\right]$

(c) Rate of work done by the electric field at P is zero

(d) Rate of work done by both the fields at Q is zero

30. A proton moving with a constant velocity passes through a region of space without any change in its velocity. If E and B represent the electric and magnetic fields respectively. Then, this region of space may have **(IIT-JEE 1985)**

(a) $E = 0, B = 0$

(b) $E = 0, B \neq 0$

(c) $E \neq 0, B = 0$

(d) $E \neq 0, B \neq 0$

Comprehension Based/Statement Based

Direction (Q. 31-32): A charged particle (electron or proton) is introduced at the origin ($x = 0, y = 0, z = 0$) with a given initial velocity v. A uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ exist everywhere. The velocity v, electric field $\vec{E}$ and magnetic field $\vec{B}$ are given in columns I, II and III, respectively. The quantities E_0, B_0 are positive in magnitude **(JEE Adv. 2017)**

Column-I		Column-II		Column-III	
(I)	Electron with $v = 2\frac{E_0}{B_0}\hat{x}$	(i)	$\vec{E} = E_0\hat{z}$	(P)	$\vec{B} = -B_0\hat{z}$
(II)	Election with $v = \frac{E_0}{B_0}\hat{y}$	(ii)	$\vec{E} = -E_0\hat{y}$	(Q)	$\vec{B} = B_0\hat{x}$
(III)	Proton with $v = 0$	(iii)	$\vec{E} = -E_0\hat{x}$	(R)	$\vec{B} = B_0\hat{y}$
(IV)	Proton with $v = 2\frac{E_0}{B_0}\hat{x}$	(iv)	$\vec{E} = E_0\hat{x}$	(S)	$\vec{B} = B_0\hat{z}$

31. In which case would the particle move in a straight line along the negative direction of Y-axis (i.e. move along $-y$)?

C-38.56 W-34.16 UA-27.28

(a) (II) (iii) (S) (b) (III) (iii) (P)

(c) (IV) (ii) (S) (d) (III) (ii) (R)

32. In which case will the particle move in a straight line with constant velocity?

C-36.93 W-30.5 UA-32.56

(a) (II) (iii) (S) (b) (III) (iii) (P)

(c) (IV) (i) (S) (d) (III) (ii) (R)

33. In which case will the particle describe a helical path with axis along the positive z-direction?

C-39.43 W-31.8 UA-28.77

(a) (II) (ii) (R) (b) (III) (iii) (P)

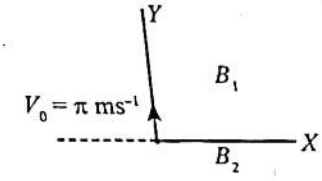
(c) (IV) (i) (S) (d) (IV) (ii) (R)

Numerical Types/Integer Types

34. An α-particle (mass 4 amu) and a singly charged sulfur ion (mass 32 amu) are initially at rest. They are accelerated through a potential V and then allowed to pass into a region of uniform magnetic field which is normal to the velocities of the particles. Within this region, the α-particle and the sulfur ion move in circular orbits of radii r_α and r_s, respectively. The ratio (r_s/r_α) is_____.

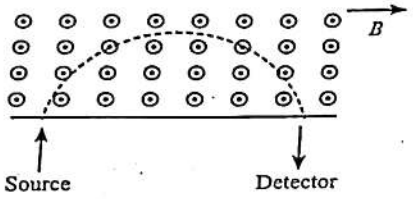
C-27.68 W-62.25 UA-10.07 (JEE Adv. 2021)

35. In the xy-plane, the region $y > 0$ has a uniform magnetic field $B_1\hat{k}$ and the region $y < 0$ has another uniform magnetic field $B_2\hat{k}$. A positively charged particle is projected from the origin along the positive Y-axis with speed $v_0 = \pi ms^{-1}$ at $t = 0$, as shown in figure. Neglect gravity in this problem. Let $t = T$ be the time when the particle crosses the X-axis from below for the time when the particle crosses the X-axis from below for the first time. If $B_2 = 4B_1$, the average speed of the particle, in ms^{-1}, along the X-axis in the time interval T is... **C-14.01 W-63.54 UA-22.45 (JEE Adv. 2018)**



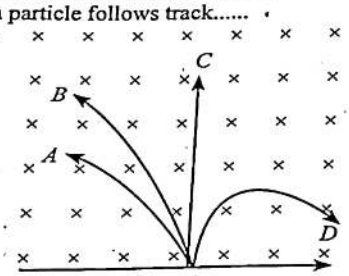
@FAKE_CBSE_X @RAJ_EDUNET

36. A uniform magnetic field with a slit system as shown in figure is to be used as a momentum filter for high-energy charged particles. With a field B Tesla, it is found that the filter transmits α-particles each of energy 5.3 *MeV*. The magnetic field is increased to 2.3 B Tesla and deuterons are passed into the filter. The energy of each deuteron transmitted by the filter is .....*MeV*. **(IIT-JEE 1997)**

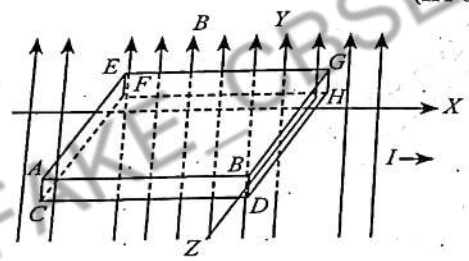


Fill in the Blanks

37. A neutron, a proton, an electron and an alpha particle enter a region of constant magnetic field with equal velocities. The magnetic field is along the inward normal to the plane of the paper. The tracks of the particles are labelled in figure. The electron follows track..... and the alpha particle follows track..... **(IIT-JEE 1984)**



38. A metallic block carrying current I is subjected to a uniform magnetic induction B as shown in figure. The moving charges experience a force F given by ..... which results in the lowering of the potential of the face ..... Assume the speed of the charges to be v. **(IIT-JEE 1996)**



True/False

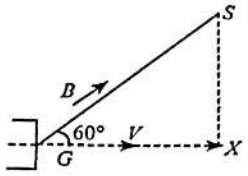
39. An electron and a proton are moving with the same kinetic energy along the same direction. When they pass through a uniform magnetic field perpendicular to the direction of their motion, they describe circular path of the same radius. **(IIT-JEE 1985)**

40. A charged particle enters a region of uniform magnetic field at an angle of 85° to the magnetic line of force. The path of the particle is a circle. **(IIT-JEE 1983)**

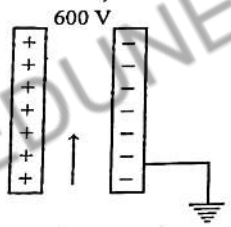
41. There is no change in the energy of a charged particle moving in magnetic field although a magnetic force is acting on it. **(IIT-JEE 1983)**

Subjective

42. An electron gun G emits electrons of energy 2 *keV* travelling in the positive x-direction. The electrons are required to hit the spot S where $GS = 0.1$ m, and the line GS make an angle of 60° with the x-axis as shown in figure. A uniform magnetic field B parallel to GS exists in the region outside the electron gun. Find the minimum value of B needed to make the electrons hit S. **(IIT-JEE 1993)**



43. A potential difference of 600 V is applied across the plates of a parallel plate condenser. The separation between the plates is 3 mm. An electron projected vertically, parallel to the plates, with a velocity of 2×10^6 m/s moves undeflected between the plates. Find the magnitude and direction of the magnetic field in the region between the condenser plates. (Neglect the edge effects). (Charge of the electron $= -1.6 \times 10^{-19}$C) **(IIT-JEE 1981)**



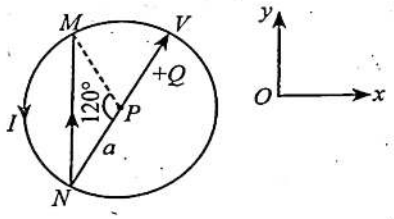
44. A proton and an alpha particle, after being accelerated through the same potential difference, enter a uniform magnetic field, the direction of which is perpendicular to their velocities. Find the ratio of radii of the circular paths of the two particles. **(IIT-JEE 2004)**

45. A particle of mass m and charge q is moving in a region where uniform, constant electric and magnetic fields E and B are present. E and B are parallel to each other. At time $t = 0$, the velocity v_0 of the particle is perpendicular to E (Assume that its speed is always $<<c$, the speed of light in vacuum). Find the velocity v of the particle at time t. You must express your answer in terms of t, q, m, the vector v_0, E and B and their magnitudes v_0, E and B. **(IIT-JEE 2000)**

46. The region between $x = 0$ and $x = L$ is filled with uniform steady magnetic field $-B_0\hat{k}$. A particle of mass m, positive charge q and velocity $v_0\hat{i}$ travels along x-axis and enters the region of the magnetic field.

Neglect the gravity throughout the question. (*a*) Find the value of L if the particle emerges from the region of magnetic field with its final velocity at an angle 30° to its initial velocity. (*b*) Find the final velocity of the particle and the time spent by it in the magnetic field, if the magnetic field now expands upto 2.1 L. **(IIT-JEE 1999)**

47. A wire loop carrying a current I is placed in the $x-y$ plane as shown in figure.



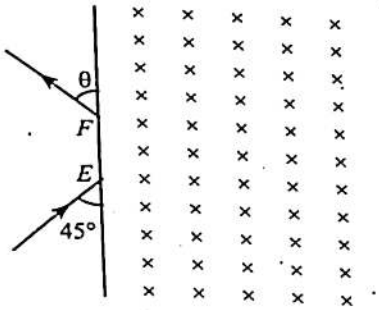
@FREE_CBSE_@RAJ_EDUNET

(a) If a particle with charge $+Q$ and mass m is placed at the centre P and given a velocity v along NP (see figure), find its instantaneous acceleration.

(b) If an external uniform magnetic induction field $B = B\hat{i}$ is applied, find the force and the torque acting on the loop due to this field. **(IIT-JEE 1991)**

48. A beam of protons with a velocity 4×10^5 m/s enters a uniform magnetic field of 0.3 T at an angle of 60° to the magnetic field. Find the radius of the helical path taken by the protons beam. Also find the pitch of the helix (which is the distance traveled by a proton in the beam parallel to the magnetic field during one period of rotation). **(IIT-JEE 1986)**

49. A particle of mass $m = 1.6 \times 10^{-27}$ kg and charge $q = 1.6 \times 10^{-19}$ C enters a region of uniform magnetic field of strength 1T along the direction shown in figure. The speed of the particle is 10^7 m/s. **(IIT-JEE 1984)**



(a) The magnetic field is directed along the inward normal to the plane of the paper. The particle leaves the region of the field at the point F. Find the distance EF and the angle θ.

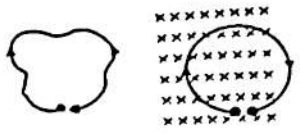
(b) If the direction of the field is along the outward normal to the plane of the paper, find the time spent by the particle in the region of the magnetic field after entering it at E.

50. A particle of mass 1×10^{-26} kg and charge $+1.6 \times 10^{-19}$ C travelling with a velocity 1.28×10^6 m/s in the $+x$ direction enters a region in which a uniform electric field E and a uniform magnetic field of induction B are present such that $E_x = E_y = 0$, $E_z = -102.4$ kV/m and $B_x = B_z = 0$, $B_y = 8 \times 10^{-2}$ T. The particle enters this region at the origin at time $t = 0$ Determine the location (x, y) and z coordinates) of the particle at $t = 5 \times 10^{-6}$ s. If the electric field is switched off at this instant (with the magnetic field still present), what will be the position of the particle at $t = 7.45 \times 10^{-6}$ s? **(IIT-JEE 1982)**

Magnetic Force on Current Carrying Wire

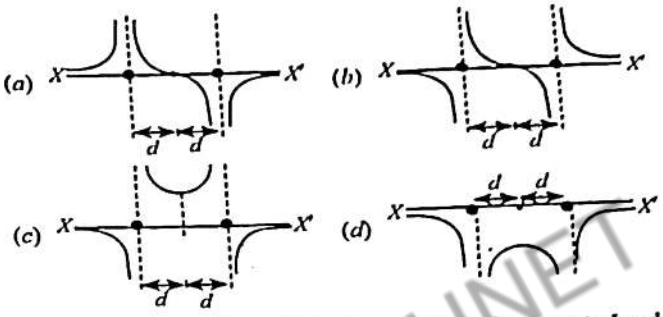
Single Correct

51. A thin flexible wire of length L is connected to two adjacent fixed points and carries a current I in the clockwise direction, as shown in the figure. When the system is put in a uniform magnetic field of strength B going into the plane of the paper, the wire takes the shape of a circle. The tension in the wire is **(IIT-JEE 2010)**



(a) IBL (b) $\frac{IBL}{\pi}$ (c) $\frac{IBL}{2\pi}$ (d) $\frac{IBL}{4\pi}$

52. Two long parallel wires are at a distance $2d$ apart. They carry steady equal currents flowing out of the plane of the paper as shown. The variation of the magnetic field B along the line XX' is given by **(IIT-JEE 2000)**



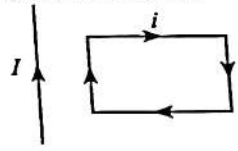
53. Two very long straight parallel wires carry steady currents I and $-I$ respectively. The distance between the wires is d. At a certain instant of time, a point charge q is at a point equidistant from the two wires in the plane of the wires. Its instantaneous velocity v is perpendicular to this plane. The magnitude of the force due to the magnetic field acting on the charge at this instant is **(IIT-JEE 1998)**

(a) $\frac{\mu_0 Iqv}{2\pi d}$ (b) $\frac{\mu_0 Iqv}{\pi d}$ (c) $\frac{2\mu_0 Iqv}{\pi d}$ (d) Zero

54. Two thin long parallel wires separated by a distance b are carrying a current i ampere each. The magnitude of the force per unit length exerted by one wire on the other is **(IIT-JEE 1986)**

(a) $\frac{\mu_0 i^2}{b^2}$ (b) $\frac{\mu_0 i^2}{2\pi b}$ (c) $\frac{\mu_0 i}{2\pi b}$ (d) $\frac{\mu_0 i}{2\pi b^2}$

55. A rectangular loop carrying a current i is situated near a long straight wire such that the wire is parallel to one of the sides of the loop and is in the plane of the loop. If steady current I is established in the wire as shown in the figure, the loop will **(IIT-JEE 1985)**



(a) Rotate about an axis parallel to the wire

(b) Move away from the wire

(c) Move toward the wire

(d) Remain stationary

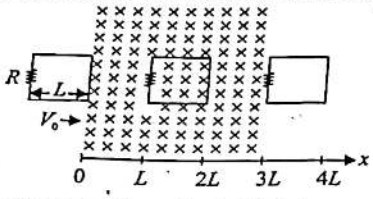
56. A conducting circular loop of radius r carries a constant current i. It is placed in a uniform magnetic field B_0 such that B_0 is perpendicular to the plane of the loop. The magnetic force acting on the loop is **(IIT-JEE 1983)**

(a) irB_0 (b) $2\pi irB_0$ (c) zero (d) πirB_0

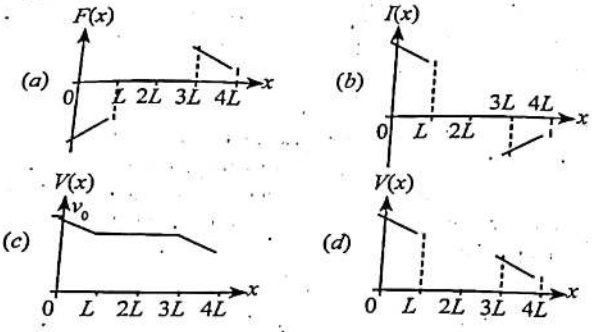
@FANTSEX @RAJEDUNET

Multiple Correct

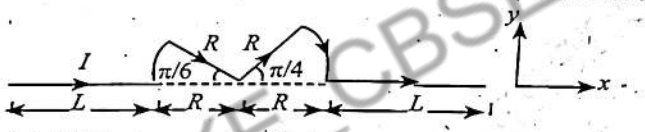
57. A rigid wire loop of square shape having side of length L and resistance R is moving along the x-axis with a constant velocity v_0 in the plane of the paper. At $t = 0$, the right edge of the loop enters a region of length $3L$, where there is a uniform magnetic field B_0 into the plane of the paper, as shown in the figure. For sufficiently large v_0, the loop eventually crosses the region. Let x be the location of the right edge of the loop. Let $v(x)$, $I(x)$ and $F(x)$ represent the velocity of the loop, current in the loop, and force on the loop, respectively, as a function of x. Counter-clockwise current is taken as positive.



Which of the following schematic plot(s) is/are correct? (Ignore gravity) **C-10.73 W-44.45 UA-27.76 PC-17.06 (JEE Adv. 2016)**



58. A conductor (shown in the figure) carrying constant current I is kept in the x–y plane in a uniform magnetic field B. If F is the magnitude of the total magnetic force acting on the conductor, then the correct statements is/are **(JEE Adv. 2015)**



(a) If B is along $\hat{z}$, $F \propto (L+R)$

(b) If B is along $\hat{x}$, $F = 0$

(c) If B is along $\hat{y}$, $F \propto (L+R)$

(d) If B is along $\hat{z}$, $F = 0$

59. A steady current I flows along an infinitely long hollow cylindrical conductor of radius R. This cylinder is placed coaxially inside an infinite solenoid of radius $2R$. The solenoid has n turns per unit length and carries a steady current I. Consider a point P at a distance r from the common axis. The correct statements (is/are)

C-7.6 W-53.92 UA-38.48 (JEE Adv. 2013)

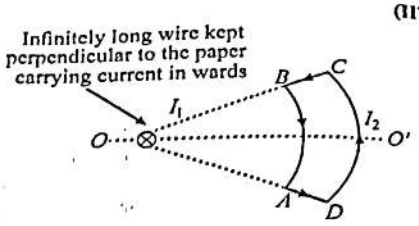
(a) In the region $0 < r < R$, the magnetic field is non-zero

(b) In the region $R < r < 2R$, the magnetic field is along the common axis

(c) In the region $R < r < 2R$, the magnetic field is tangential to the circle of radius r, centered on the axis

(d) In the region $r > 2R$, the magnetic field is non-zero

60. Which of the following statement is/are correct in the given figure? **(IIT-JEE 2006)**



(a) Net force on the loop is zero

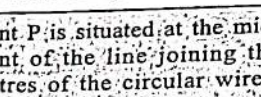
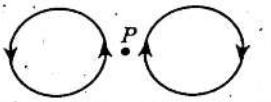
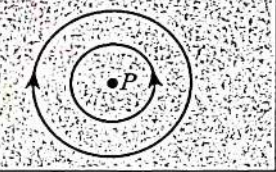
(b) Net torque on the loop is zero

(c) Loop will rotate clockwise about axis OO' when seen from O

(d) Loop will rotate anticlockwise about OO' when seen from O

Match the Column

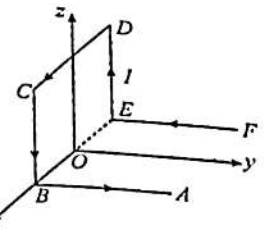
61. Two wires each carrying a steady current $-I$ are shown in four configurations in Column-I. Some of the resulting effects are described in Column-II. Match the statements in Column-I with the statements in Column-II **(IIT-JEE 2007)**

Column-I		Column-II	
(A)	Point P is situated midway between the wires. 	(p)	The magnetic fields (B) at P due to the currents in the wires are in the same direction.
(B)	Point P is situated at the mid-point of the line joining the centres of the circular wires, which have same radii.	(q)	The magnetic fields (B) at P due to the currents in the wires are in opposite directions.
(C)	Point P is situated at the common centre of the wires. 	(r)	There is no magnetic field at P.
(D)	Point P is situated at the common centre of the wires. 	(s)	The wires repel each other.

Fill in the Blanks

62. A wire $ABCDEF$ (with each side of length L) bent as shown in figure and carrying a current I is placed in a uniform magnetic induction B parallel to the positive y-direction. The force experienced by the wire is .....in the ..... direction. **(IIT-JEE 1990)**

@FAKE CBSE @RAJ_BHANET



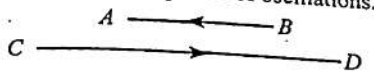
63. A wire of length L metre carrying a current I ampere is bent in the form of circle. The magnitude of its magnetic moment is ___ in MKS units. **(IIT-JEE 1987)**

True/False

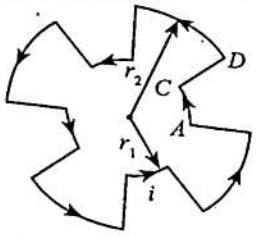
64. No net force acts on a rectangular coil carrying a steady current when suspended freely in a uniform magnetic field **(IIT-JEE1981)**

Subjective

65. A long horizontal wire AB, which is free to move in a vertical plane and carries a steady current of 20 A, is in equilibrium at a height of 0.01 m over another parallel long wire CD which is fixed in a horizontal plane and carries a steady current of 30 A, as shown in figure. Show that when AB is slightly depressed, it executes simple harmonic motion. Find the period of oscillations. **(IIT-JEE 1994)**



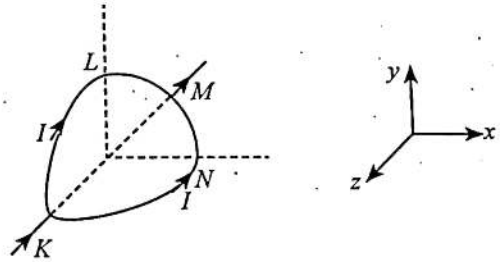
66. A current of 10 A flows around a closed path in a circuit which is in the horizontal plane as shown in the figure. The circuit consists of eight alternating arcs of radii $r_1 = 0.8$ m and $r_2 = 0.12$ m. Each subtends the same angle at the centre. **(IIT-JEE 2001)**



(*a*) Find the magnetic field produced by this circuit at the centre.

(*b*) An infinitely long straight wire carrying a current of 10 A is passing through the centre of the above circuit vertically with the direction of the current being into the plane of the circuit. What is the force acting on the wire at the centre due to the current in the circuit? What is the force acting on the arc AC and the straight segment CD due to the current at the centre?

67. A circular loop of radius R is bent along a diameter and given a shape as shown in figure. One of the semicircles (KNM) lies in the x–z plane and the other one (KLM) in the y–z plane with their centres at origin. Current I is flowing through each of the semicircles as shown in figure.



(*a*) A particle of charge q is released at the origin with a velocity $v = -v_0\hat{i}$. Find the instantaneous force F on the particle. Assume that space is gravity free.

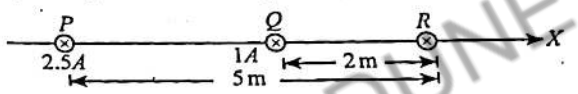
(*b*) If an external uniform magnetic field $B_0\hat{j}$ is applied determine the force F_1 and F_2 on the semicircles KLM and KNM due to the field and the net force F on the loop. **(IIT-JEE 2000)**

68. Three infinitely long thin wires, each carrying current I in the same direction, are in the $x - y$ plane of a gravity free space. The central wire is along the y-axis while the other two are along $x = \pm d$.

(*a*) Find the locus of the points for which the magnetic field B is zero.

(*b*) If the central wire is displaced along the z-direction by a small amount and released, show that it will execute simple harmonic motion. If the linear density of the wires is λ, find the frequency of oscillation **(IIT-JEE 1997)**

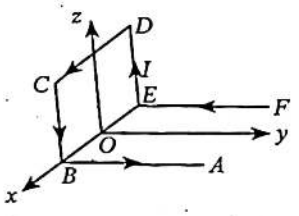
69. Two long parallel wires carrying currents 2.5 A and I (ampere) in the same direction (directed into the plane of the paper) are held at P and Q respectively such that they are perpendicular to the plane of paper. The points P and Q are located at a distance of 5 m and 2 m respectively from a collinear point R (see figure).



(*a*) An electron moving with a velocity of 4×10^5 m/s along the positive x-direction experiences a force of magnitude 3.2×10^{-20} N at the point R. Find the value of I.

(*b*) Find all the positions at which a third long parallel wire carrying a current of magnitude 2.5 A may be placed, so that the magnetic induction at R is zero. **(IIT-JEE 1990)**

70. A wire $ABCDEF$ (with each side of length L) bent as shown in figure and carrying a current I is placed in a uniform magnetic induction B parallel to the positive y-direction. The force experienced by the wire is in the direction. **(IIT-JEE 1990)**



Comprehension Based/Statement Based

Paragraph

A special metal S conducts electricity without any resistance. A closed wire loop, made of S, does not allow any change in flux through itself by inducing a suitable current to generate a compensating flux. The induced current in the loop cannot decay due to its zero resistance. This current gives rise to a magnetic moment which in turn repels the source of magnetic field or flux. Consider such a loop, of radius a, with its center at the origin. A magnetic dipole of moment m is brought along the axis of this loop from infinity to a point at distance r ($>> a$) from the center of the loop with its north pole always facing the loop, as shown in the figure below.

@AMIT_CBSE X @RAJ_EDUNET

The magnitude of magnetic field of a dipole m, at a point on its axis at distance r, is $\frac{\mu_0}{2\pi}\frac{m}{r^3}$, where μ_0 is the permeability of free space. The magnitude of the force between two magnetic dipoles with moments, m_1 and m_2, separated by a distance r on the common axis, with their north poles facing each other, is $\frac{km_1m_2}{r^4}$, where k is a constant of appropriate dimensions. The direction of this force is along the line joining the two dipoles. **(JEE Adv. 2021)**

71. When the dipole m is placed at a distance r from the center of the loop (as shown in the figure), the current induced in the loop will be proportional to **C-18.32 W-31.02 UA-50.66**

(a) m/r^3 (b) m^2/r^2 (c) m/r^2 (d) m^2/r

72. The work done in bringing the dipole from infinity to a distance r from the center of the loop by the given process is proportional to **C-11.42 W-34.44 UA-54.14**

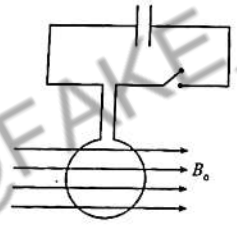
(a) m/r^5 (b) m^2/r^5 (c) m^2/r^6 (d) m^2/r^7

Torque and Potential Energy of Coil in External Magnetic Field

Single Correct

73. A circular coil of radius R and N turns has negligible resistance. As shown in the schematic figure, its two ends are connected to two wires and it is hanging by those wires with its plane being vertical. The wires are connected to a capacitor with charge Q through a switch. The coil is in a horizontal uniform magnetic field B parallel to the plane of the coil. When the switch is closed, the capacitor gets discharged through the coil in a very short time. By the time the capacitor is discharged fully, magnitude of the angular momentum gained by the coil will be (assume that the discharge time is so short that the coil has hardly rotated during this time)

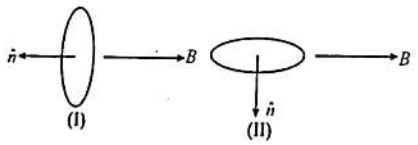
C-15.91 W-28.13 UA-55.96 PC-0 (JEE Adv. 2020)

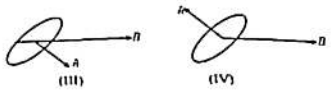


(a) $\frac{\pi}{2}NQB_0R^2$ (b) πNQB_0R^2

(c) $2\pi NQB_0R^2$ (d) $4\pi NQB_0R^2$

74. A current carrying loop is placed in a uniform magnetic field in four different orientations, I, II, III and IV. Arrange them in the decreasing order of potential energy. **(IIT-JEE 2003)**





(a) I > III > II > IV (b) I > II > III > IV

(c) I > IV > II > III (d) III > IV > I > II

75. A magnetic needle is kept in a non-uniform magnetic field. It experiences **(IIT-JEE 1982)**

(a) a force and a torque

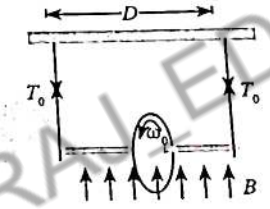
(b) a force but not a torque

(c) a torque but not a force

(d) neither a force nor a torque

Subjective

76. A ring of radius R having uniformly distributed charge Q is mounted on a rod suspended by two identical strings. The tension in strings in equilibrium is T_0. Now, a vertical magnetic field is switched on and ring is rotated at constant angular velocity ω. Find the maximum ω with which the ring can be rotated if the strings can withstand a maximum tension of $3T_0/2$. **(IIT-JEE 2003)**

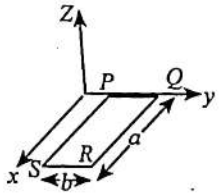


77. A rectangular loop $PQRS$ made from a uniform wire has length a, width b and mass m. It is free to rotate about the arm PQ, which remains hinged along a horizontal line taken as the y-axis (see figure). Take the vertically upward direction as the z-axis. A uniform magnetic field $B = (3\hat{i} + 4\hat{k})B_0$ exists in the region. The loop is held in the $x-y$ plane and a current I is passed through it. The loop is now released and is found to stay in the horizontal position in equilibrium. **(IIT-JEE 2002)**

(a) What is the direction of the current I in PQ?

(b) Find the magnetic force on the arm RS.

(c) Find the expression for I in terms of B_0, a, b and m.



78. A moving coil galvanometer experiences a torque = ki, where i is current. If N coils of area A each and moment of inertia I is kept in magnetic field B. **(IIT-JEE 2005)**

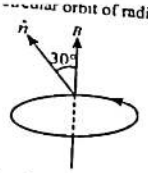
(a) Find k in terms of given parameters.

(b) If for current i deflection is $\frac{\pi}{2}$, find out torsional constant of spring.

(c) If a charge Q is passed suddenly through the galvanometer, find out maximum angle of deflection.

@FAKE_CBSE_X@RAJEDUPET

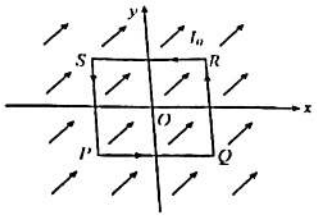
clockwise ... circular orbit of radius R. ... revolving in anti- **(IIT-JEE 1996)**



(*a*) Obtain an expression for the orbital magnetic moment of the electron.

(*b*) The atom is placed in a uniform magnetic induction B such that the normal to the plane of electron's orbit makes an angle of 30° with the magnetic induction. Find the torque experienced by the orbiting electron.

50. A uniform constant magnetic field B is directed at an angle of 45° to the x-axis in x-y plane. $PQRS$ is rigid square wire frame carrying a steady current I_0, with its centre at the origin O. At time $t = 0$, the frame is at rest in the position shown in the figure with its sides parallel to x and y-axes. Each side of the frame is of mass M and length L. **(IIT-JEE 1998)**



(*a*) What is the magnitude of torque τ acting on the frame due to the magnetic field?

(*b*) Find the angle by which the frame rotates under the action of this torque in a short interval of time Δt and the axis about which this rotation occurs (Δt is so short that any variation in the torque during this interval may be neglected). Given : the moment of inertia of the frame about an axis through its centre perpendicular to its plane is $\frac{4}{3}ML^2$

@FREECBSE X @RAJ_EDUNET

ANSWER KEY

JEE-Main

1. [160]	2. [3.00]	3. (*c*)	4. [40]	5. [72]	6. [5]	7. [2]	8. [2]	9. (*d*)	10. (*c*)
11. (*d*)	12. (*c*)	13. (*d*)	14. (*c*)	15. (*e*)	16. [68]	17. [628]	18. [2]	19. [40]	20. [8]
21. (*b*)	22. (*c*)	23. (*c*)	24. (*c*)	25. (*b*)	26. (*b*)	27. (*d*)	28. (*c*)	29. (a,b)	30. (*d*)
31. (*b*)	32. (*d*)	33. (*c*)	34. (*d*)	35. (*d*)	36. (*a*)	37. (*d*)	38. [20]	39. (*c*)	40. [500]
41. (*c*)	42. (*b*)	43. (*b*)	44. (*c*)	45. (*a*)	46. (*d*)	47. (*d*)	48. (*c*)	49. (*b*)	50. [32]
51. [5]	52. (2)	53. (*c*)	54. (*d*)	55. (*c*)	56. (*c*)	57. (*a*)	58. (*b*)	59. [144]	60. [40]
61. (*a*)	62. (*b*)	63. (*d*)	64. (*b*)	65. (*c*)	66. (*c*)	67. (*c*)	68. (*c*)	69. (*a*)	70. [136]
71. [2]	72. [10]	73. (*a*)	74. (*d*)	75. (*c*)	76. (*b*)	77. (*c*)	78. (*a*)	79. (*d*)	80. (*c*)
81. (*a*)	82. (*d*)	83. (*c*)	84. (*c*)	85. (*d*)	86. (*a*)	87. (*b*)	88. (*a*)	89. (*c*)	90. (*)
91. (*a*)	92. (*d*)	93. [35]	94. (*d*)	95. [50]	96. [5]	97. [160]	98. (*a*)	99. (*d*)	100. (*b*)
101. [2]	102. (*b*)	103. (*c*)	104. (*b*)	105. (*b*)	106. [4]	107. [5]	108. [2]	109. [100]	110. (*b*)
111. (*a*)	112. (*d*)	113. (*b*)							

JEE-Advanced

1. (*c*)	2. (*a*)	3. (*a*)	4. (*c*)	5. (*d*)	6. (*d*)	7. (*a*, *b*)	8. (*a*, *b*, *d*)	9. [3]	10. [5]
11. [7]	14. (*d*)	15. (*b*)	16. (*a*)	17. (*a*)	18. (*d*)	19. (*b*)	20. (*c*)	21. (*b*)	22. (*a*)
23. (*c*)	24. (*a*, *d*)	25. (*a*, *c*)	26. (*b*, *d*)	27. (*c*, *d*)	28. (*a*,*c*,*d*)	29. (*a*,*b*,*d*)	30. (*a*,*b*,*d*)	31. (*c*)	32. (*a*)
33. (*c*)	34. [4]	35. [2]	36. [14]	39. [False]	40. [False]	41. [True]	51. (*c*)	52. (*b*)	53. (*d*)
54. (*b*)	55. (*c*)	56. (*c*)	57. (*b*, *c*)	58. (*a*, *b*, *c*)	59. (*a*,*d*)	60. (*a*, *c*)	61. (*A-q,r B-p C-q,r D-q*)		
64. [True]	71. (*a*)	72. (*c*)	73. (*b*)	74. (*c*)	75. (*a*)				

EXPLANATIONS

JEE-Main

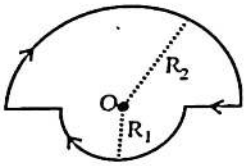
1. [160] Magnetic field point p

$$B=\left(\frac{\mu_0 I}{2\pi a}\right)\times 2=\frac{4\pi\times10^{-7}\times10}{\pi\times\left(\frac{5}{2}\times10^{-2}\right)}$$

$$=16\times10^{-5}=160\mu T$$

2. [3.00]

$$B=\frac{\mu_0 i}{2R_2}\left(\frac{\pi}{2\pi}\right)\otimes+\frac{\mu_0 i}{2R_1}\left(\frac{\pi}{2\pi}\right)\otimes$$



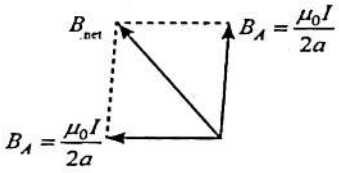
$$\Rightarrow B=\left(\frac{\mu_0 i}{4R_2}+\frac{\mu_0 i}{4R_1}\right)\otimes$$

$$\Rightarrow B=\frac{4\pi\times10^{-7}\times4}{4\times4\pi}+\frac{4\pi\times10^{-7}\times4}{4\times2\pi}$$

$$=3\times10^{-7}=\alpha\times10^{-7}$$

$\alpha=3$

3. (c) As we know, Magnetic field due to circular wire at its center $=\frac{\mu_0 I}{2a}$



Hence, $B_{net}=\frac{\sqrt{2}\mu_0 I}{2a}$

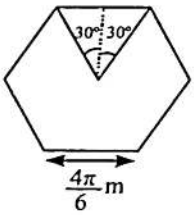
4. [40] Given, Current $I=5A$
Side $=1m$

$$B=4\times\frac{\mu_0 i}{4\pi\left(\frac{1}{2}\right)}\left(\frac{1}{\sqrt{2}}+\frac{1}{\sqrt{2}}\right)$$

$$=4\times10^{-7}\times5\times2\times\sqrt{2}$$

$$=40\sqrt{2}\times10^{-7}\,T$$

5. [72] $B=6\left(\frac{\mu_0 I}{4\pi r}\right)\left(\sin30^\circ+\sin30^\circ\right)$



$$=6\frac{10^{-7}\times4\pi\sqrt{3}}{\left(\frac{\sqrt{3}\times4\pi}{2\times6}\right)}=72\times10^{-7}T$$

6. [5] $B_C=\frac{\mu_0(2I)}{2\pi r}+\frac{\mu_0 I}{2\pi(3r)}=\frac{7\mu_0 I}{6\pi r}$

$$B_A=\frac{\mu_0 I}{2\pi r}+\frac{\mu_0(2I)}{2\pi(3r)}=\frac{5\mu_0 I}{6\pi r}$$

$$\therefore\frac{B_A}{B_C}=\frac{5}{7}$$

$\therefore x=5$

7. [2] Given, $\vec{r}=0.5\hat{j},\Delta l=\Delta x\hat{i}$

$$\overrightarrow{dB}=\frac{\mu_0 I}{4\pi}\frac{(\vec{dl}\times\vec{r})}{r^3}$$

$$\overline{dB}=\frac{10^{-7}\times10\times\left(\frac{1}{2}\times\frac{1}{100}\right)}{\left(\frac{1}{2}\right)^3}$$

$$=4\times10^{-8}T$$

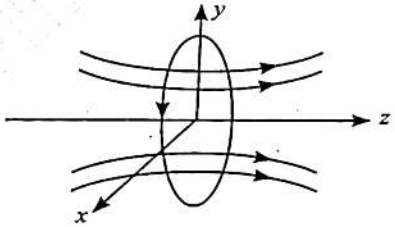
8. [2] $\vec{E}_p=\left(\frac{\sigma}{2\varepsilon_0}+\frac{2\sigma}{2\varepsilon_0}+\frac{\sigma}{2\varepsilon_0}\right)(-\hat{i})$

$$=-\frac{2\sigma}{e_0}\hat{i}$$

9. (d) Magnetic field at the centre of a semicircular arc is,

$$=\frac{\mu_0 I}{4R}=\frac{4\pi\times10^{-7}\times3}{4\times\frac{\pi}{10}}\Rightarrow B_O=3\mu T$$

10. (c) Magnetic field at the center of the coil must be zero, therefore option (a) and (d) are ruled out.



Magnetic field at centre are along z direction so $B_y=0$

For $z>0$ B_y is + ve

For $z<0$ B_y is − ve

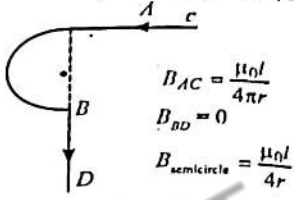
As the magnetic field to the left and to the right of the origin must be in opposite directions, so option (c) is correct.

11. (d) Magnetic field at point O due to current in BC and ET is

$$B_0=\frac{\mu_0 I}{4\pi\frac{a}{2}}+\frac{\mu_0 I}{4\pi\frac{a}{2}}=\frac{\mu_0 I}{\pi a}$$

Due to AB & ED field is zero.

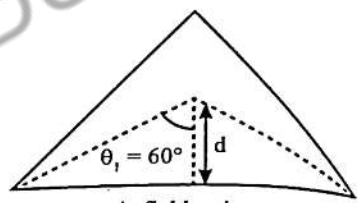
12. (c) $B_r=\left(\frac{\mu_0 I}{4r}+\frac{\mu_0 I}{4\pi r}\right)=\frac{\mu_0 I}{2r}\left(\frac{1}{2}+\frac{1}{2\pi}\right)$



13. (d) Magnetic field due to any side of the triangle

$$B=\frac{\mu_0 I}{4\pi d}(\sin\theta_1+\sin\theta_2)$$

$d\tan60^\circ=2\sqrt{3}\Rightarrow d=2$ cm



Total magnetic field at the centroid of the triangle

$$B=3\times\frac{\mu_0 i}{2\pi d}\sin60^\circ$$

$$=3\times\frac{2\times10^{-7}\times2}{2\times10^{-2}}\times\frac{\sqrt{3}}{2},=3\sqrt{3}\times10^{-5}T$$

14. (c) Magnetic field due to a current carrying circular loop at any point on its axis is given by

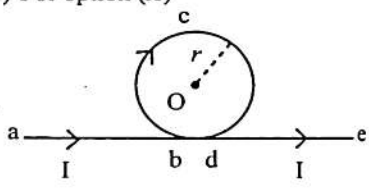
$$B=\frac{\mu_0 i r^2}{2\left(r^2+x^2\right)^{3/2}}$$

At centre, $x=0,B_1=\frac{\mu_0 i}{2r}$

At $x=r,B_2=\frac{\mu_0 i}{2\times2\sqrt{2}r}$

$$\Rightarrow\frac{B_1}{B_2}=2\sqrt{2}$$

15. (c) For option (A)



@FAKE_CBSE_K @RAJ_EDUNET

$B_{ab} = \frac{\mu_0}{4\pi}\frac{I}{r}$ (outwards)

$B_{bcd} = \frac{\mu_0}{4\pi}\frac{I}{r}(2\pi)$ (inwards)

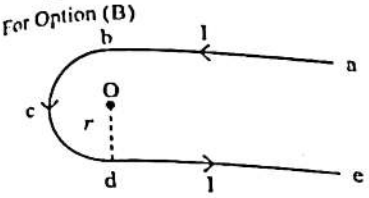
$B_{de} = \frac{\mu_0}{4\pi}\frac{I}{r}$ (outwards)

Hence magnetic field at O is

$B_0 = -\frac{\mu_0}{4\pi}\frac{I}{r} + \frac{\mu_0}{4\pi}\frac{I}{r}(2\pi) - \frac{\mu_0}{4\pi}\frac{I}{r}$

$B_0 = \frac{\mu_0}{2\pi}\frac{I}{r}(\pi - 1)$ ...option (III)

For Option (B)



$B_{ab} = \frac{\mu_0}{4\pi}\frac{I}{r}$ (outwards)

$B_{bcd} = \frac{\mu_0}{4\pi}\frac{I}{r}(\pi)$ (outwards)

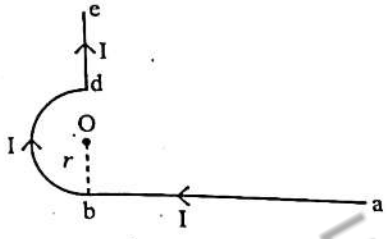
$B_{de} = \frac{\mu_0}{4\pi}\frac{I}{r}$ (outwards)

Hence magnetic field at O is

$B_0 = \frac{\mu_0}{4\pi}\frac{I}{r} + \frac{\mu_0}{4\pi}\frac{I}{r}(\pi) + \frac{\mu_0}{4\pi}\frac{I}{r}$

$B_0 = \frac{\mu_0}{4\pi}\frac{I}{r}(\pi + 2)$... option (I)

For option (C)



$B_{ab} = \frac{\mu_0}{4\pi}\frac{I}{r}$ (inwards)

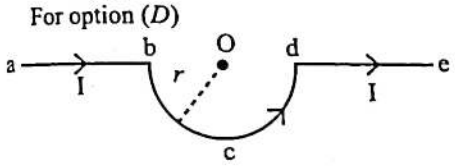
$B_{bcd} = \frac{\mu_0}{4\pi}\frac{I}{r}(\pi)$ (inwards)

$B_{de} = 0$ (at point O)

Hence magnetic field at O is

$B_0 = \frac{\mu_0}{4\pi}\frac{I}{r}(1 + \pi)$ ...option (IV)

For option (D)



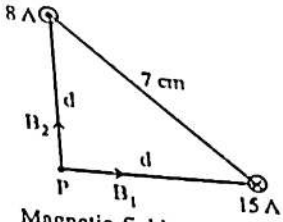
$B_{ab} = 0$ (at point O)

$B_{bcd} = \frac{\mu_0}{4\pi}\frac{I}{r}(\pi)$ (outwards)

$B_{de} = 0$ (outwards)

Hence magnetic field at O is $B_0 = \frac{\mu_0 I}{4r}$ ...option (II)

16. [68]



Magnetic fields produced by both the wires will be perpendicular to each other.

$B_1 = \frac{\mu_0 i_1}{2\pi d}$ and $B_2 = \frac{\mu_0 i_2}{2\pi d}$

$B_{net} = \sqrt{B_1^2 + B_2^2}$

$= \frac{\mu_0}{2\pi d}\sqrt{i_1^2 + i_2^2}$

$= \frac{4\pi\times10^{-7}}{2\pi\times\left(7/\sqrt{2}\right)\times10^{-2}} \times \sqrt{8^2 + 15^2}$

$B_{net} = 68 \times 10^{-6}$ T

17. [628]

$B_y = |B_x| = \frac{\mu_0 I}{2r}$

$= \frac{4\pi\times10^{-7}}{2\times0.2} \times \sqrt{2}T$

Net magnetic field at the centre,

$B_{net} = B\sqrt{2} = \frac{4\pi\times10^{-7}\times\sqrt{2}}{2\times0.2} \times \sqrt{2}T$

$= 2\pi\times10^{-6}$ N

$= 628 \times 10^{-6}$ T

18. [2] $B_O = B_{wire} + B_{semicircle}$

$B_O = 0 + \frac{\mu_0 I}{4R} = \frac{4\pi\times10^{-7}\times14}{4\times2.2\times10^{-2}}$

$B_O = 2 \times 10^{-4}$ T

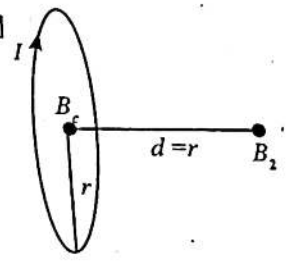
19. [40] From Biot-savart law

$B = \frac{\mu_0}{4\pi}\frac{qv\sin\theta}{r^2} = \frac{\mu_0}{4\pi}\frac{ev}{r^2}\left(\because \sin\frac{\pi}{2} = 1\right)$

$B = \frac{\mu_0}{4\pi}\frac{ev\sin(\pi/2)}{r^2}$

$B = \frac{10^{-7}\times1.6\times10^{-19}\times6.76\times10^6}{0.52\times0.52\times10^{-20}} = 40T$

20. [8]



Magnetic field due to current carrying coil at a point situated at a distance d on axial line

$B = \frac{\mu_0 IR r^2}{2(r^2 + d^2)^{3/2}}$

Magnetic field at cente, $d = 0$

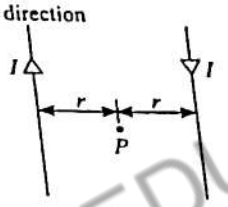
$B_c = \frac{\mu_0 Ir^2}{2r^3} = \frac{\mu_0 I}{2r}$

Magnetic field at $d = r$

$B_d = \frac{\mu_0 Ir^2}{2(r^2 + r^2)^{3/2}} = \frac{\mu_0 I}{4\sqrt{2}\cdot r}$

$\frac{B_c}{B_d} = \frac{\mu_0 I}{2r} \times \frac{4\sqrt{2}r}{\mu_0 I} = \frac{2\sqrt{2}}{1} = \frac{\sqrt{8}}{1}$ $x = 8$

21. (b) As we know that, if currents are flowing in same direction, magnetic field will cancel each other. Therefore, the currents must flowing in opposite direction

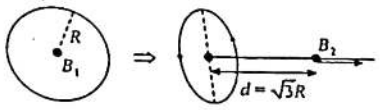


$B_P = \frac{\mu_0 I}{2\pi r} + \frac{\mu_0 I}{2\pi r} = \frac{\mu_0 I}{2\pi r} \times 2$

$\Rightarrow 300\times10^{-6} = \frac{4\pi\times10^{-7} I}{2\pi\times4\times10^{-2}} \times 2$

$\Rightarrow I = 30$ A

22. (c)



$B_1 = \frac{\mu_0 i}{2R}$

$B_2 = \frac{\mu_0 iR^2}{2\left(R^2 + (\sqrt{3}R)^2\right)^{3/2}}$

$= \frac{\mu_0 iR^2}{2\times8R^3} = \frac{\mu_0 i}{8\times2R} = \frac{B_1}{8}$

$\Rightarrow$ Required ratio, $\frac{B_1}{B_2} = 8:1$

23. (c) $B_C = \frac{\mu_0 I}{2r}, B_a = \frac{\mu_0 Ir^2}{2\left(x^2 + r^2\right)^{3/2}}$

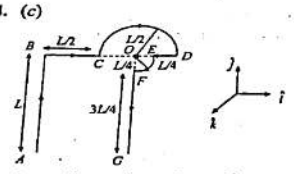
At $x = \frac{r}{2}$, $B_a = \frac{\mu_0 Ir^2}{2\left(\frac{r^2}{4} + r^2\right)^{3/2}}$

$= \frac{\mu_0 Ir^2}{2\left(\frac{5}{4}r^2\right)^{3/2}} = \frac{\mu_0 I}{2r}\left(\frac{4}{5}\right)^{3/2}$

$= \frac{\mu_0 I}{2r}\left(\frac{2}{\sqrt{5}}\right)^3 = \left(\frac{2}{\sqrt{5}}\right)^3 B$

@FAKE_CBSE_RAJ_EDUNET

24. (c)



$\vec{B}_{Net} = \vec{B}_{AB} + \vec{B}_{BC} + \vec{B}_{CD} + \vec{B}_{DE} + \vec{B}_{EF} + \vec{B}_{FG}$

$\vec{B}_{BC} = \vec{B}_{DE} = \vec{B}_{FG} = 0$

$\vec{B}_{AB} = \frac{\mu_0 I}{4\pi L}\sin 45^\circ\left[-\hat{k}\right]$

$\vec{B}_{CD} = \frac{\mu_0 I}{4\left(\frac{L}{2}\right)^2}\left[-\hat{k}\right]$

$\vec{B}_{EF} = \frac{\mu_0 I}{8\left(\frac{L}{4}\right)^2}\left[-\hat{k}\right]$

25. (b) Number of turns = N

Inner radius = a, outer radius = b,

Consider an elementary portion of radius r and thickness dr.

Number of turns in elementary portion,

$dN = \frac{N}{2\pi(b-a)}\cdot 2\pi dr = \frac{N}{(b-a)}dr$

∴ (dB) at centre =

$\frac{\mu_0 IdN}{2r} \Rightarrow B = \int_a^b \frac{\mu_0 I}{2r}\times\left(\frac{N}{b-a}\right)$

$\Rightarrow B = \frac{\mu oIN}{2(b-a)} In\left(\frac{b}{a}\right)$

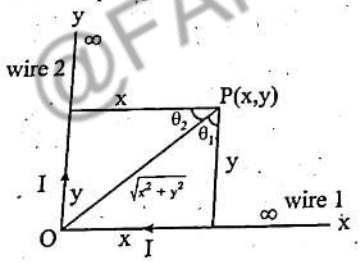
26. (b) B due to wire 1,

$B_1 = \frac{\mu_0 I}{4\pi y}[\sin\theta_1 + \sin 90^\circ]$ ...(i)

B due to wire 2

$B_2 = \frac{\mu_0 I}{4\pi x}[\sin\theta_2 + \sin 90^\circ]$

So $B = B_1 + B_2$



$B = \frac{\mu_0 I}{4\pi}\left[\frac{1}{y}\left(1+\frac{x}{\sqrt{x^2+y^2}}\right) + \frac{1}{x}\left(1+\frac{y}{\sqrt{x^2+y^2}}\right)\right]F$

$B = \frac{\mu_0 I}{4\pi}\left[\frac{1}{y}+\frac{1}{x}+\frac{x}{y\sqrt{x^2+y^2}} + \frac{y}{x\sqrt{x^2+y^2}}\right]$

$B = \frac{\mu_0 I}{4\pi}\left[\frac{x+y}{xy} + \frac{x^2+y^2}{xy\sqrt{x^2+y^2}}\right]$

$B = \frac{\mu_0 I}{4\pi xy}\left[(x+y)+\sqrt{x^2+y^2}\right]$

27. (d) Step 1. Given data

A hairpin is made by bending a long current-carrying wire.

Step 2. Finding the magnitude of the magnetic field at the point P:

Magnetic field due to each of the straight wire = $\frac{\mu_0 I}{4\pi r}$

Magnetic field due to semicircular arc = $\frac{\mu_0 I}{4r}$

Thus, the total magnetic field at a point P is given by

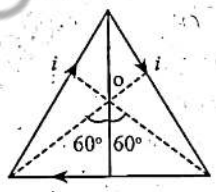
$B = \frac{\mu_0 I}{4\pi r} + \frac{\mu_0 I}{4\pi r} + \frac{\mu_0 I}{4r}$

$B = \frac{\mu_0 I}{2\pi r} + \frac{\mu_0 I}{4r}$

$B = \frac{\mu_0 I}{4\pi r}(2+\pi)$

28. (c) $B = \frac{\mu_0 i}{4\pi r}(\sin\theta_1 + \sin\theta_2)$

$= \frac{10^{-7}\times 1.5}{\left(\frac{0.09}{2\sqrt{3}}\right)}\times(\sin 60^\circ + \sin 60^\circ) = 10^{-5}\,T$



Net magnetic field at centroid is $B_{net} = 3 \times 10^{-5}$ T

inside the plane

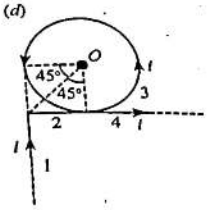
29. (a,b) Magnetic field at the plane of the ring is perpendicular to the plane. However, they bend as they move forward Due to symmetry it depends only on

$r = \sqrt{x^2+y^2}$

but as we approach towards first loop B_1 increases to infinity, so B_1 dominates.

So it would be zero at some point between inner loops and centre.

30. (d)



The net magnetic field

$\frac{\mu_0 I}{4\pi R}[\sin 90^\circ - \sin 45^\circ]\otimes + \frac{\mu_0 I}{2R}\odot$

$+\frac{\mu_0 I}{4\pi R}(\sin 45^\circ + \sin 90^\circ)\odot$

$\frac{-\mu_0 I}{4\pi R}\left[1-\frac{1}{\sqrt{2}}\right] + \frac{\mu_0 I}{2R}$

$+\frac{\mu_0 I}{4\pi R}\left[\frac{1}{\sqrt{2}}+1\right]\odot$

$\frac{\mu_0 i}{4\pi R}\left[\sqrt{2}+2\pi\right]\odot = \frac{\mu_0 i}{2\pi R}\left[\frac{1}{\sqrt{2}}+\pi\right]\odot$

31. (b) $B_A = \frac{(\mu_0)(2)\,3(\pi/2)}{(2)(2)\,2\pi}$ ...(i)

$B_B = \frac{(\mu_0)(3)\,5\pi/3}{(2)(4)\,2\pi}$ ...(ii)

From (i) and (ii) $\frac{B_A}{B_B} = \frac{6}{5}$

32. (d) $B_C = \frac{\mu_0 i}{2R}$, $B_C = \frac{\mu_0 Ni}{2(R/N)}$

$\therefore \frac{B_L}{B_C} = \frac{1}{N^2}$

33. (c) $B = 2\left[\frac{\mu_0 i}{4\pi d}(\cos\theta_1 - \cos\theta_2)\right]$

$B = 10^{-4}$

$\mu_0 = 4\pi\times 10^{-7}$, $\theta_1 = 90^\circ$, $\theta_2 = 180^\circ$

$d = 4\times 10^{-2} \Rightarrow = 20$ A (into the page)

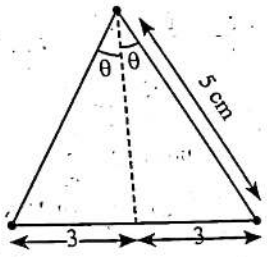
34. (d) $B = \frac{\mu_0 I}{4\pi d}2\sin\theta$

$d = 4$ cm

$\sin q = \frac{3}{5}$

$B = 10^{-7}\times\frac{5\times 2}{4\times 10^{-2}}\left(\frac{3}{5}\right)$

$B = 1.5\times 10^{-5}\,T$



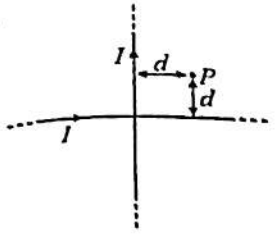
@FAKE_CBSE_X @RAJ_BOUNET

35. (d) $B=\frac{\mu_0 i}{2R}=\frac{\mu_0 q\omega}{2R2\pi}\Rightarrow q=\frac{B.4\pi R}{\mu_0\omega}$

$q=\frac{(3.8\times10^{-9})(4\pi\times10^{-1})}{(4\pi\times10^{-7})(40\pi)}$

$q=3\times10^{-7}\,C$

36. (a)



Magnetic field at point P

$\vec{B}_{net}=\frac{\mu_0 i}{2\pi d}(-\hat{k})+\frac{\mu_0 i}{2\pi d}(\hat{k})=0$

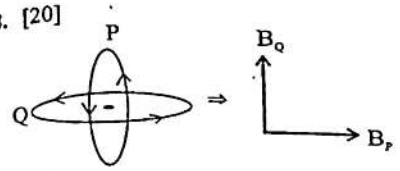
37. (d) Magnetic field at centre due to current carrying loop subtending angle θ at the centre, $B=\frac{\mu_0 I}{4\pi r}\theta$.

Hence, θ is in radian.

$B=\left(\frac{\mu_0}{4\pi}\right)\times10\left(\frac{1}{3\times10^{-2}}-\frac{1}{5\times10^{-2}}\right)\frac{\pi}{4}$

$\Rightarrow B=\frac{\pi}{40}\times10^{-4}=\frac{\pi}{4}\times10^{-5}\approx10^{-5}$

38. [20]



Magnetic Field at point P,

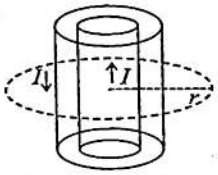
$B_P=\frac{\mu_0 N i_1}{2r}=\frac{\mu_0\times1\times100}{2\pi}=2\times10^{-3}\,T$

$B_Q=\frac{\mu_0 N i_2}{2r}=\frac{\mu_0\times2\times100}{2\pi}=4\times10^{-3}\,T$

$B_{net}=\sqrt{B_P^2+B_Q^2}=\sqrt{20}\,\text{mT}$

$x=20$

39. (c)



Consider loop as shown

here $\oint\vec{B}.d\vec{\ell}=\mu_0 i_{enc}=0$

$\therefore\ B=0$ outside the cable

40. [500]

Magnetic field the inside the solenoid, $B=\mu_0 ni$

$\mu_0\left(\frac{m}{\ell}\right)I=B$

$m=\frac{B.\ell}{\mu_0 I}=\frac{6.28\times10^{-3}\times0.5}{12.56\times10^{-7}\times5}$

$m=500$

41. (c) From circuital law

$B_1 2\pi\frac{a}{2}=\mu_0\frac{I}{4}$

$B_1=\frac{\mu_0 I}{4\pi a}$ (I)

$B_2 2\pi 2a=\mu_0 I$

$B_2=\frac{\mu_0 I}{4\pi a}$ (II)

From (i) and (ii) we get the required ratio 1 : 1

42. (b) Statement I is true but Statement II is false

43. (b) $H=\frac{B}{\mu_0}=\frac{\mu_0 ni}{\mu_0}=ni\Rightarrow i=\frac{H}{n}$

$i=\frac{1.6\times10^3}{\left(\frac{8}{10^{-2}}\right)}=0.2\times10^3\times10^{-2}=2A$

44. (c) It is given that, Final kinetic energy ($K.E_f$) = 4 times Initial kinetic energy ($K.E_i$)

We know that $r\propto\sqrt{k\cdot E}$

$\therefore\frac{r_f}{r_0}=\frac{\sqrt{k\cdot E_f}}{k\cdot E_i}$

$\frac{r_f}{r_0}=\frac{\sqrt{4k.E_i}}{\sqrt{k.E_i}}$

$\frac{r_f}{r_0}=\frac{2}{1}=2:1$

45. (a) We know that, $B=n\mu_0 I'$

According to equations $I'=2I$

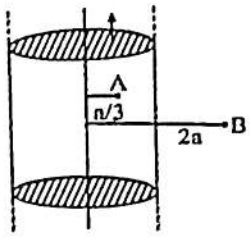
$n'=n/2$

$B'=\frac{n}{2}\mu_0 2I=B$

46. (d) $B_A=\frac{\mu_0 ir}{2\pi a^2}=\frac{\mu_0 i\frac{a}{3}}{2\pi a^2}=\frac{\mu_0 i}{\pi a^2}\frac{a}{6}=\frac{\mu_0 i}{6\pi a}$

$B_B=\frac{\mu_0 i}{2\pi(2a)}$

$\frac{B_A}{B_B}=\frac{4}{6}=\frac{2}{3}$



47. (d)

48. (c) $\vec{F}_E=q\vec{E}$ and $\vec{F}_B=q(\vec{V}\times\vec{B})$

Net force on particle must be zero i.e.

$q\vec{E}+q\vec{V}\times\vec{B}=0$

Possible cases are

(i) $\vec{E}\ \&\ \vec{B}=0$

(ii) $\vec{V}\times\vec{B}=0,\vec{E}=0$

(iii) $q\vec{E}=-q\vec{V}\times\vec{B}$

$\vec{E}\neq0\ \&\ \vec{B}\neq0$

49. (b) Radius of circular path

$R=\frac{mv}{qB}=\frac{p}{qB}=\frac{\sqrt{2m(KE)}}{qB}=\frac{\sqrt{2mqV}}{qB}$

$R\ \mu\ \sqrt{m}$

$m\propto R^2$

mass ratio of X and Y is

$\frac{m_1}{m_2}=\left(\frac{R_1}{R_2}\right)$

50. [32] $q=4\,\mu C,\ \vec{v}=4\times10^6\,\hat{j}$ m/s

$\vec{B}=2\hat{k}T$

The force acting on the charge is

$F=q(\vec{v}\times B)=4\times10^{-6}\left(4\times10^6\,\hat{j}\times2\hat{k}\right)$

$=4\times10^{-6}\times8\times10^6\,\hat{i}$

$\vec{F}=32\hat{i}$ N

$x=32$

51. [5] Lorentz Force, $\vec{F}=q(\vec{v}\times\vec{B})$

$5e\hat{k}=e\left(3\hat{i}+5\hat{j}\right)\times\left(B_0\hat{i}+2B_0\hat{j}\right)$

$5e\hat{k}=e\left(6B_0\hat{k}-5B_0\hat{k}\right)$

$\Rightarrow B_0=5T$

52. (2) Since $\vec{v}$ is parallel to $\vec{B}$ hence force on electron due to magnetic field is zero. So electron will move along axis with uniform velocity.

53. (c) The electrostatics force on a charge particle $=q\vec{E}$

The magnetic force on the charge particle $=q(\vec{V}\times\vec{B})$

54. (d) Net force on the electron should be zero so that it moves along the same path.

$qE=qVB$

$E=VB$

@FAKE_CBSE_X@RAJ_EDUNET

$$= \sqrt{\frac{2\times KE}{m}} \times B$$

$$= \sqrt{\frac{2\times 5\times 1.6\times 10^{-19}}{9\times 10^{-31}}} \times 3\times 10^{-6} = 4\,N/C$$

55. (c) Hence magnetic field is uniform, now radius of the path,

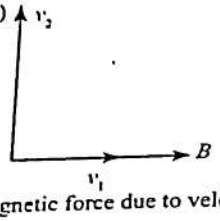
$$R = \frac{mv}{qB} = \frac{\sqrt{2m(K.E)}}{qB} \Rightarrow R \propto \frac{\sqrt{m}}{q}$$

$$\therefore \frac{R_{deutron}}{R_{proton}} = \sqrt{\frac{m_d}{m_p}} \times \frac{q_p}{q_d} = \sqrt{2} \times 1$$

The ratio of the radius of deutron and proton path,

$\therefore \gamma_d : \gamma_p = \sqrt{2} : 1$

56. (c)



Magnetic force due to velocity component v_1

$F = qv_1 B \sin\theta = 0$

So v_1 will same.

Because of velocity component v_2, magnetic force act towards centre i.e. moving it circular.

Hence path is helical with the axis along magnetic field B.

57. (a) Force on the $\bar{e}$, $\bar{F} = -e(\bar{v}\times\bar{B})$

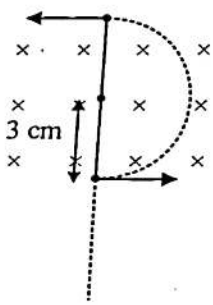
Form right hand thumb rule force will be along -ve y-axis.

Since, magnetic force is $\perp$ to velocity, therefore path of electron would be a circle.

58. (b) $\bar{F} = q(\bar{v}\times\bar{B})$ as angle between $\bar{v}$ and $\bar{B}$ is $0°$ $\bar{F} = 0$, $\bar{e}$ will not experience force. In the solenoid, magnetic field lie along the axis of solenoid.

59. [144] $r = \frac{mv}{qB} = \frac{\sqrt{2km}}{qB}, m = \frac{r^2q^2B^2}{2k}$

$$m = \frac{r^2q^2B^2}{2k}$$



$$\frac{1}{100}\times\frac{3}{100}\times 2\times 2\times 4$$

$$m = \frac{\times 10^{-3}\times 4\times 10^{-3}\times 10^{-12}}{2\times(100)\times 10^{-6}}$$

$\therefore m = 144\times 10^{-18}$ kg

60. [40]

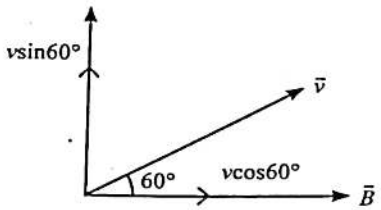
$$B = \frac{\pi}{2}\times 10^{-3}$$

$$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2\times 2\times 1.6\times 10^{-19}}{1.6\times 10^{-27}}}$$

$v = 2\times 10^4$ m/sec

Time period of one rotation $= \frac{2\pi m}{eB}$

$$T = \frac{2\pi\times 1.6\times 10^{-27}}{1.6\times 10^{-19}\times\frac{\pi}{2}\times 10^{-3}} = 4\times 10^{-5}\text{ sec}$$



Pitch $= (v\cos 60°)T$

Pitch $= 2\times 10^4\times\frac{1}{2}\times 4\times 10^{-5} = 40$ cm

61. (a) The magnetic force acts perpendicularly to the velocity of the particle. Thus, no work is done by the force on the particle. Hence, speed and energy of the particle remains constant.

62. (b) $\bar{a}.\bar{B} = 0$

$$(\alpha\hat{i} - 4\hat{j}).(2\hat{i} + 3\hat{j}) = 0$$

$\alpha(2) + (-4)(3) = 0$

$$\alpha = \frac{12}{2} \Rightarrow \alpha = 6$$

63. (d) We know that, $r = \sqrt{\frac{2mKE}{qB}}$

$$\therefore r \propto \sqrt{\frac{m}{q}}$$

Let us suppose,

$m_p = m, q_p = q, m_d = 2m, q_d = q, m\alpha = 4m, q\alpha = 2q.$

$$\therefore r_p : r_d : r_\alpha = \frac{\sqrt{m_p}}{q_p} : \frac{\sqrt{m_d}}{q_d} : \frac{\sqrt{m_\alpha}}{q_\alpha}$$

$$= \frac{\sqrt{m}}{q} : \frac{\sqrt{2m}}{q} : \frac{\sqrt{4m}}{2q} = 1 : \sqrt{2} : 1$$

$$\therefore r_p : r_d : r_\alpha = 1 : \sqrt{2} : 1$$

64. (b) Radius of circular path R $= \frac{\sqrt{2mE}}{qB}$

$$q = \frac{\sqrt{2mE}}{RB}$$

Kinetic energy and magnetic field are constant, therefore, $q \propto \frac{\sqrt{m}}{R}$

$$\Rightarrow \frac{q_1}{q_2} = \sqrt{\frac{m_1}{m_2}} \times \frac{R_2}{R_1} = \sqrt{\frac{9}{4}} \times \frac{5}{6} = \frac{5}{4}$$

65. (c)

$$f = \frac{1}{T} = \frac{qB}{2\pi m} = \frac{1.6\times 10^{-19}\times 1.0\times 10^{-4}}{2\times 3.14\times 9\times 10^{-31}}$$

$= 0.025\times 10^9$ Hz $= 2.8\times 10^6$ Hz

66. (c) $\frac{r_\alpha}{r_p} = \frac{m_\alpha q_p}{m_p q_\alpha}$

($\because r = \frac{mv}{qB}$, v & B are constant)

$$= \frac{4m}{m}\left(\frac{q}{2q}\right) = 2:1$$

67. (c) When a particle moves in a uniform magnetic field, The force due to magnetic field on it is perpendicular to its velocity, Because, Force $\bar{F} = q(\bar{v}\times\bar{B})$

Since the magnetic field is constant, so force is constant. Hence, its direction of velocity constantly changes but magnitude of velocity remains same.

Hence the particle moves in circular motion Since magnitude of velocity does not changes, Hence kinetic energy also does not change.

Statement-II is incorrect because the velocity of the particle is affected by magnetic field. Its direction changes

68. (c) $E_y = 900\sin\omega\left(t - \frac{x}{c}\right)$

Comparing with $E_y = E_0\sin\omega\left(t - \frac{x}{c}\right)$, $E_0 = 900$

Given, speed of charge, $v = 3\times 10^7$ m/s

$$\therefore \frac{F_E}{F_B} = \frac{qE}{|vB_0|} = \frac{c}{V} = \frac{3\times 10^8}{3\times 10^7} = 10$$

$$\Rightarrow \frac{F_E}{F_B} = \frac{10}{1}$$

69. (a) $KE = 728\times 1.6\times 10^{-19} = \frac{1}{2}\times 9.1\times 10^{-31}\times v^2$

$\Rightarrow v = 16\times 10^6$ m/s

For lorentz force to be zero

$\Rightarrow eE = eVB$

$\Rightarrow E = vB = 16\times 10^6\times 12\times 10^{-3}$

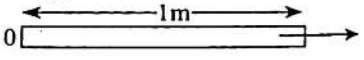
$= 192\times 10^3$ V/m

70. [136] Given, current, $i = 1A$

Area, $A = 2\text{mm}^2$

$\rho = 1.7\times 10^{-8}\,\Omega$m

Resistivity, $= 1.7\times 10^{-8}\,\Omega$m



@RAKE_CBSE_KORAJ_EDUCATION

$\because J = \sigma E$, $\sigma = \frac{1}{\rho}$, and $J = \frac{I}{A}$

Therefore, Force on e^-,

$F = eE = \frac{ej}{\sigma} = \frac{ei}{A\sigma} = \frac{ei\rho}{A}$

$= \frac{1.6\times10^{-19}\times1.7\times10^{-8}}{2\times10^{-6}}$

$= 0.8 \times 1.7 \times 10^{-21}$

$= 136 \times 10^{-23}$ N

71. [2] Since, radii of circular path,

$r = \frac{mv}{qB}$

$\because p = mv = \sqrt{2m(K.E)}$

$\therefore r = \frac{\sqrt{2m(K.E)}}{qB}$

For constant K.E, $r \propto \frac{\sqrt{m}}{q}$

$\frac{r_d}{r_P} = \frac{\sqrt{m_d}}{\sqrt{m_P}} \times \frac{q_P}{q_d}$

$= \frac{\sqrt{2m_P}}{\sqrt{m_P}} \times \frac{q_P}{q_d}$ $[q_P = q_d = 1.6 \times 10^{-19}\text{C}]$

$= \sqrt{2}:1$

72. [10]

$r = \frac{mv}{qB} = \frac{\sqrt{2m\cdot K}}{qB}$

$= \frac{\sqrt{2\times24\times1.66\times10^{-27}\times5\times10^{3}\times1.6\times10^{-19}}}{1.6\times10^{-19}\times0.5}$

$= 9.975 \times 10^{-2}$ cm

$r \approx 10$ cm

73. (*a*) We know that, charge on deutron and alpha particle is e and $2e$ respectively. Mass of deutron and alpha particle is 2m and 4m respectively.

As we know that radius of circular path in magnetic field is given as

$r = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB}$

$\frac{r_d}{r_\alpha} = \sqrt{\frac{m_d}{m_\alpha}} \times \frac{q_\alpha}{q_d} = \frac{1}{\sqrt{2}} \times 2 = \sqrt{2}$

74. (*d*) As we know that radius of trajectory is given as

$R = \frac{\sqrt{2mK}}{qB} \Rightarrow K = \frac{R^2q^2B^2}{2m}$

$\frac{K_p}{K_\alpha} = \frac{R_p^2q_p^2B^2}{2m_p} \times \frac{2m_\alpha}{R_\alpha^2q_\alpha^2B^2}$

$\Rightarrow \quad = \left(\frac{m_\alpha}{m_p}\right) \times \left(\frac{R_p}{R_\alpha}\right)^2 \times \left(\frac{q_p}{q_\alpha}\right)^2$

$\Rightarrow \frac{K_p}{K_\alpha} = (4) \times (2)^2 \times \left(\frac{1}{2}\right)^2 = 4:1$

75. (*c*) Radius of a charge particle moving in circular path in perpendicular magnetic field can be given as,

$R = \frac{\sqrt{2Em}}{B.q}$

$\Rightarrow R \propto \frac{\sqrt{m}}{q}$

$\Rightarrow \frac{R_1}{R_2} = \frac{\sqrt{4}}{\sqrt{16}} \times \frac{3}{2} = \frac{3}{4}$

$\Rightarrow R_2 = \frac{4R_1}{3}$

$\sin\theta = \frac{d}{R} \Rightarrow \theta \alpha \frac{1}{R} \Rightarrow \theta_2 < \theta_1$

76. (*b*) Magnetic force acting on a charge particle is

$\vec{F} = q(\vec{v} \times \vec{B})$

$W = \vec{F} \cdot d\vec{\ell}$

Since, magnetic force acting on point charge and displacement will be always perpendicular.

So, $W = F.S$

$\Rightarrow W = 0$

77. (*c*) Given, $\frac{q_1}{q_2} = \frac{1}{2}, \frac{v_1}{v_2} = \frac{2}{3}$

Radius of the circular trajectory in the magnetic field.

$r = \frac{mv}{qB}$, $\therefore \frac{r_1}{r_2} = \left(\frac{m_1}{m_2}\right)\left(\frac{q_2}{q_1}\right)\left(\frac{v_1}{v_2}\right)$

$\frac{r_1}{r_2} = 2 \times \frac{2}{3} = \frac{4}{3}$

78. (*a*) Charge

Mass

Proton e m

α-particle 2e 4m

Deuteron e 2m

Speed, $v = P/m$

$v_1 = \frac{P}{m}, v_2 = \frac{P}{2m}, v_3 = \frac{P}{4m}$

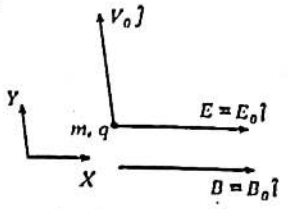
$\therefore v_1 : v_2 : v_3 = 4:2:1$

$F = qvB = \frac{qPB}{m}$

$F_1 = \frac{qPB}{m}, F_2 = \frac{q \times P \times B}{2m}, F_3 = \frac{2qPB}{4m}$

$\therefore F_1 : F_2 : F_3 = 4:2:2 = 2:1:1$

79. (*d*)



$(2V_0)^2 = v_0^2 + v_z^2 ; v_z = \sqrt{3}v_0$

$\therefore \sqrt{3}v_0 = 0 + \frac{eE}{m}t \Rightarrow ; t = \frac{mv_0\sqrt{3}}{qE}$

80. (*c*) Force an the electron,

$F = q(\vec{E} + \vec{V} \times \vec{B})$, $\vec{E} + \vec{V} \times \vec{B} = 0$

81. (*a*) $\ell = 10 \times$ pitch

$= 10 \times v \cos 60° \times \frac{2\pi m}{qB}$

$= \frac{20\times3.14\times1.67\times10^{-27}\times4\times10^{5}\times\frac{1}{2}}{1.6\times10^{-19}\times0.3}$

$= 4.36 \times 10^{-1}$ m $= 0.44$ m.

82. (*d*) $F = q(\vec{V} \times \vec{B})$

$= (1 \times 10^{-6})$

$[2\hat{i} + 3\hat{j} + 4\hat{k}] \times [5\hat{i} + 3\hat{j} - 6\hat{k}] \times 10^{-3}$

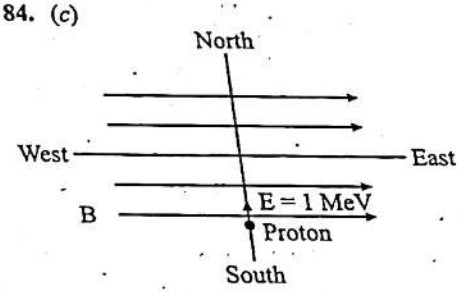
$= (-30\hat{i} + 32\hat{j} - 9\hat{k})10^{-9}$ N

83. (*c*) The cyclotron equation is $r = \frac{mv}{qB_0}$

When charged particle should not hit the screen

$\Rightarrow \frac{mv}{qB_0} < d$, $\therefore V_{max} = \frac{qB_0d}{m}$

84. (*c*)



$\because K.E. = 1.6 \times 10^{-13} = \frac{1}{2} \times 1.6 \times 10^{-27} v^2$

$v = \sqrt{2} \times 10^7$ m/s

$\therefore Bqv = ma$

$B = \frac{1.6\times10^{-27}\times10^{12}}{1.6\times10^{-19}\times\sqrt{2}\times10^{7}}$

$= 0.71 \times 10^{-3}$ T

So, 0.71 mT

@MAKE_CBSE_EASY@RAJ_EDUNET

85. (*d*) Pitch $= v\cos\theta \times \frac{2\pi m}{qB}$

$= 4\times10^5 \times \frac{1}{2} \times \frac{2\pi\times1.67\times10^{-27}}{1.69\times10^{-19}\times0.3} = 4$ cm

86. (*a*) $R_{max} = \frac{R}{2} = \frac{mv_{max}}{e\mu_0 nI}$

$V_{max} = \frac{Re\mu_0 nI}{2m}$

87. (*b*) Time period of oscillation,

$T_0 = 2\pi\sqrt{\frac{m}{k}} = \frac{2\pi}{\sqrt{10}}$

For damped oscillation, amplitude is given as

$A = A_0 e^{-t/\gamma}$

$\therefore$ for $A = \frac{A_0}{e}, t = \gamma$

$t = \gamma = \frac{2m}{b} = \frac{2m}{\frac{B^2\ell^2}{R}} = 10^4 s$

$\therefore$ No of oscillation,

$N = \frac{t}{T_0} = \frac{10^4}{2\pi/\sqrt{10}} \approx 5000$

88. (*a*) $\bar{\tau} = \bar{M}\times\bar{B}$

$\Rightarrow |\bar{\tau}| = MB\sin 90° = C\theta$

$\Rightarrow$ MB = Cθ $\Rightarrow$ Cθ = i N A B

$\Rightarrow 10^{-6}\times\frac{\pi}{180} = 10^{-3}\times10^{-4}\times175\times B$

$\Rightarrow$ B = 10^{-3}Tesla.

89. (*c*) $r = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB}$

$\Rightarrow r_{He} = r_p > r_e$

90. (*) $\hat{a} = -\left(\frac{d\sqrt{3}\hat{i}+d\hat{j}}{\sqrt{(d\sqrt{3})^2+d^2}}\right) = \frac{-\sqrt{3}\hat{i}-\hat{j}}{2}$

$\therefore$ Acceleration,

$\bar{a} = \frac{F}{m}\hat{a} = \frac{qVB}{m}\left(\frac{-\sqrt{3}\hat{i}-\hat{j}}{2}\right)$ (Bonus)

91. (*a*) $m_p = m$

$q_p = q$, $K_p = qV = K$, $m\alpha = 4m$, $q\alpha = 2q$

$K\alpha = 2qV = 2K$

Radius of circular path,

$r = \frac{mv}{qB} = \frac{\sqrt{2Km}}{qB} = \sqrt{\frac{2mV}{qB^2}} \Rightarrow \frac{r_p}{r_\alpha} = \frac{1}{\sqrt{2}}$

92. (*d*) Radius, $r = \frac{mv}{qB} = \frac{\sqrt{2mqv}}{qB}$

$r = \frac{\sqrt{\frac{2mv}{q}}}{B} = \frac{\sqrt{\frac{2\times9.1\times10^{-31}\times500}{1.6\times10^{-19}}}}{100\times10^{-3}}$

$r = 7.5\times10^{-4}$ m

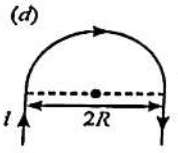
93. [35] Given, $B_H = 3.5\times10^{-5}$ T and $\theta = 90°$

As we know, $F = IlB\sin\theta$, $l = \sqrt{2}A$

The force per unit length is,

$\frac{F}{\ell} = lB\sin\theta = \sqrt{2}\times3.5\times10^{-5}\times\frac{1}{\sqrt{2}}$

94. (*d*)



$\bar{F} = i\bar{\ell}\times\bar{B}$ (Direction of magnetic field is in $\hat{k}$)

$\ell = 2R$

$\bar{F} = -2iRB\hat{j}$

95. [50] Here F_{net} will be due to portion parallel to y-axis, because force on segment parallel to x-axis will cancel each other.

$F = 0.5\times0.5\times6\times0.2 - 0.5\times0.5\times0.2\times5$

$= 0.5\times0.5\times0.2 = 50\times10^{-3}$ N

$= 50$ mN

96. [5] Resistance of the current carrying wire,

$R = \frac{\rho\ell}{A} \Rightarrow \frac{2\times10^{-6}\times\ell}{10^{-5}} = 1$

$\Rightarrow l = 5$m

Net force in the vertical direction is zero, so

$mg = Bi\ell$

$B = \frac{mg}{i\ell} = \frac{5}{2\times5} = 0.5$

$= 5\times10^{-1}$ Tesla

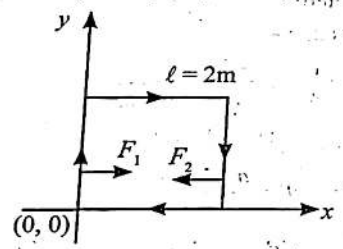
97. [160]

Given; $\ell = 2m$ and $i = 2A$

$B(x=0) = B_0$, $B(x=2) = 9B_0$

Also, $F = i\ell B$

$\Rightarrow F_1 = i\ell B_0$ & $F_2 = 9i\ell B_0$



$F = F_2 - F_1 = 8i\ell B_0 = 8\times2\times2\times5$

$F = 160$ N

98. (*a*) Force per unit length between two parallel straight current carrying wires $= \frac{\mu_0 I_1 I_2}{2\pi d}$

$\Rightarrow \frac{F_1}{F_2} = \frac{\frac{\mu_0(10)^2}{2\pi(5cm)}}{\frac{\mu_0(20)^2}{2\pi\left(\frac{5cm}{2}\right)}} = \frac{1}{8}$

$\Rightarrow F_2 = 8F_1$

99. (*d*) $F_m = mg$

$\therefore ILB = mg$

$\therefore \left(\frac{V}{R}\right)LB = mg$, $\therefore V = \frac{mgR}{LB}$

$= \frac{(1\times10^{-3}\,kg)(10\,m/s^2)(10\Omega)}{(0.1m)(10^3\times10^{-4}\,T)} = 10V$

100. (*b*) Force between two parallel current carrying wires

$F \propto I_1 I_2$

$\Rightarrow F_1 : F_{21} = 1:4$

101. [2] For equilibrium, Gravitational force acting on the wire = Magnetic force on the wire

$Mg = I\ell B$

$I = \frac{mg}{\ell B} = \frac{40\times10^{-3}\times10}{50\times10^{-2}\times0.4} = 2A$

102. (*b*) Net force of charge,

$\vec{F}_{net} = q\vec{E} + q(\vec{v}\times\vec{B})$

$= q\vec{E} + q|\vec{v}||\vec{B}|\sin90°$

$= (2q\hat{i} + 3q\hat{j} + 0)$

Work done W

$= \vec{F}_{net}\cdot\vec{S} = (2q\hat{i}+3q\hat{j})\cdot(\hat{i}+\hat{j})$

$= 2q + 3q = 5q$

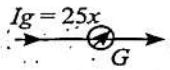
103. (*c*) $I \propto \theta$ (angle of deflection)

$\therefore \frac{I_2}{I_1} = \frac{\theta_2}{\theta_1} \Rightarrow \frac{I_2}{200\mu A} = \frac{\pi/10}{\pi/3} = \frac{3}{10}$

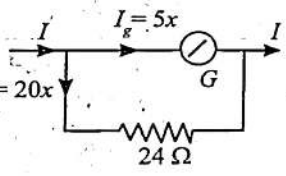
$\Rightarrow I_2 = 60\ \mu$A

104. (*b*) Given shunt = 24 Ω

Let x = current/division



After applying shunt deflection in moving coil galvanometer falls from 25 divisions to 5 division



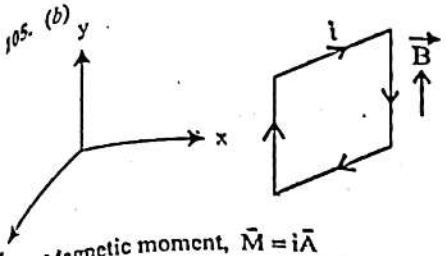
@FAKE_CBSE_QRAL_EDUNET

Now $5x \times G = 20x \times 24$

$G = 4 \times 24$

$G = 96\ \Omega$

105. (b)



Magnetic moment, $\vec{M} = i\vec{A}$

$= 5 \times (0.2) \times (0.1) \times (-\hat{i})$

$= 0.1(-\hat{i})$

Torque,

$\vec{\tau} = \vec{M} \times \vec{B} = 0.1(-\hat{i}) \times \left(2 \times 10^{-3}\right)(\hat{j})$

$= 2 \times 10^{-4}\ (-\hat{k})\ \text{N} - \text{m}$

Direction of torque of loop is $(-\hat{k})$

106. [4] $\tau = BINA\sin\phi$

$C\theta = \text{BINA}\sin 90°$ $[\because \tau = C\theta]$

$\Rightarrow C = \dfrac{\text{BINA}}{\theta}$

$= \dfrac{0.01 \times 10 \times 10^{-3} \times 100 \times 2 \times 10^{-4}}{0.05}$

$= 4 \times 10^{-5}$ N-m/rad.

$\therefore x = 4$

107. [5] The current, $I = \dfrac{V}{R}$

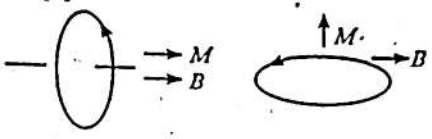
$I = K\theta$

$\dfrac{2}{G+R} = K\theta$

$\Rightarrow \dfrac{1}{\theta} = \dfrac{(G+R)K}{2} = R\left(\dfrac{K}{2}\right) + \dfrac{KG}{2}$

Slope $= \dfrac{K}{2} = \dfrac{1}{4} \Rightarrow K = 0.5 = 5 \times 10^{-1}$ A

108. [2]



initial final

$W_2 = \Delta U$

$\because (\Delta U = -\vec{M} \cdot \vec{B})$

$\left(-\vec{M} \cdot \vec{B}\right)_f - \left(-\vec{M} \cdot \vec{B}\right)_i$

$= -\text{MB}\cos 90° + \text{MB}\cos 0°$

$= \text{MB} = \text{NIAB}$

$= 200 \times 100 \times 1^{-6} \times \dfrac{5}{2} \times 10^{-4} \times 1 = 5\ \mu\text{J}$

109. [100] $W = \Delta U = U_2 - U_1$

$W = (-\vec{\mu}.\vec{B})_2 - (-\vec{\mu}.\vec{B})_1$

$= 0 + (\vec{\mu}.\vec{B})_1 = 100\text{gJ}$

$= (100 \times 5 \times 10^{-3} \times 1 \times 10^{-3}) \times 0.2\ \text{J}$

$= 1 \times 10^{-4}\ \text{J} = 100\mu\text{J}$

110. (b) The eddy currents are setup due to motion of coil which oppose the motion of coil thus bringing the coil to rest.

111. (a) Current sensitivity is the deflection (ϕ) per unit current (I) i.e., $\dfrac{\phi}{I} = \dfrac{NAB}{K}$

Voltage sensitivity,

$\dfrac{\phi}{V} = \dfrac{\phi}{IR_g} = \dfrac{\text{current sensitivity}}{R_g}$

Voltage sensitivity $\propto$ current sensitivity (when R_g is constant)

So percentage change in V_g is 25%

112. (d) Current sensitivity $= \dfrac{BNA}{k}$

Current sensitivity $\propto N$

As N is doubled then current sensitivity is doubled.

Voltage sensitivity $= \dfrac{BNA}{kR}$

Voltage sensitivity $\propto \dfrac{N}{R}$

As N is doubled R is also doubled.

So, there is no change in voltage sensitivity.

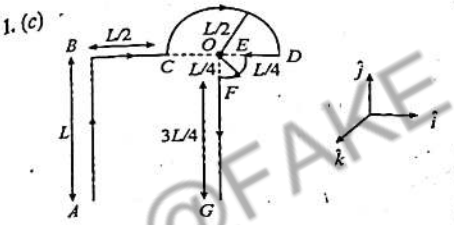
113. (b) Torque experienced by circular loop z

$\tau = 1\pi R^2 NB_0$ (at the instant shown)

Now, $d\vec{L} = \vec{\tau}dt = i\pi R^2 NB_0\, dt = Q\pi R^2 \text{NB}_0$ $[idt = Q]$

JEE-Advanced

1. (c)



$\vec{B}_{\text{Net}} = \vec{B}_{AB} + \vec{B}_{BC} + \vec{B}_{CD} + \vec{B}_{DE} + \vec{B}_{EF} + \vec{B}_{FG}$

$\vec{B}_{BC} = \vec{B}_{DE} = \vec{B}_{FG} = 0$

$\vec{B}_{AB} = \dfrac{\mu_0 I}{4\pi L}\sin 45°\left[-\hat{k}\right]$

$\vec{B}_{CD} = \dfrac{\mu_0 I}{4\left(\dfrac{L}{2}\right)}\left[-\hat{k}\right]$

$\vec{B}_{EF} = \dfrac{\mu_0 I}{8\left(\dfrac{L}{4}\right)}\left[-\hat{k}\right]$

$B_{\text{net}} = \left(\dfrac{\mu_0 I}{4\sqrt{2}\pi L} + \dfrac{\mu_0 I}{2L} + \dfrac{\mu_0 I}{2L}\right)\left(-\hat{k}\right)$

$B_{\text{net}} = \dfrac{\mu_0 I}{L}\left(1 + \dfrac{1}{4\sqrt{2}\pi}\right)\left(-\hat{k}\right)$

2. (a) Let us consider an elementary ring of radius and thickness in which current is flowing.

Number of turns in this elementary ring

$dN = \dfrac{N}{b-a}dr$

Thus magnetic field at the centre O due to this ring, $dB = \dfrac{\mu_0 IdN}{2r}$

We get $dB = \dfrac{\mu_0 INdr}{2(b-a)r}$

Net magnetic field at centre of spiral

$B = \dfrac{\mu_0 IN}{2(b-a)}\int_a^b \dfrac{dr}{r}$

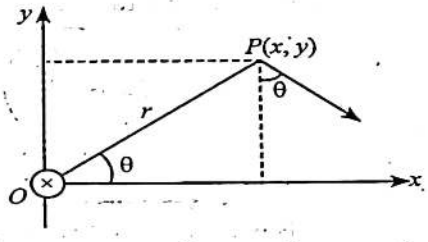
$B = \dfrac{\mu_0 IN}{2(b-a)}\left[lnr\right]_a^b$

$B = \dfrac{\mu_0 IN}{2(b-a)} ln\dfrac{b}{a}$

3. (a) The wires carries current I in the negative Z- direction

We have to consider the magnetic vector field be at x, y in the $z = 0$ plane

Magnetic field B is perpendicular to OP



We know that, $\vec{B} = B\sin\theta\hat{i} - B\cos\theta\hat{j}$

$\sin\theta = \dfrac{y}{r}$, $\cos\theta = \dfrac{x}{r}$

$r = \sqrt{x^2 + y^2}$

$B = \dfrac{\mu_0 I}{2\pi r}$

After putting all the value we get,

Hence vector $B = \dfrac{\mu_0 I(y\hat{i} - x\hat{j})}{2\pi(x^2 + y^2)}$

@FAKE_CBSE_X @RAJ_EDUNET

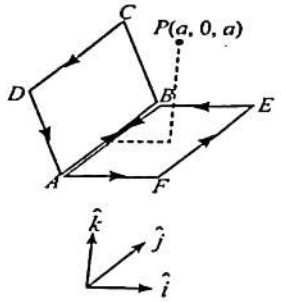
4. (c) $B_1 = \frac{\mu_0 I}{4\pi R}$

$$B_2 = \frac{\mu_0 I}{4\pi R} + \frac{\mu_0 I(1/2)}{4\pi R}$$

$$B_2 = \frac{\mu_0 I}{4\pi R}\left(\frac{3}{2}\right)$$

Hence, $\left(\frac{B_1}{B_2}\right) = \frac{2}{3}$

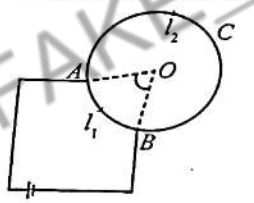
5. (d) The magnetic field at $p\ (a, 0, a)$ due to the loop is equal to the vector sum of the magnetic fields produced by loops $ABCD$ and $AFEBA$ as shown in the figure.



Magnetic field due to loop $ABCD$ will be along positive x direction and due to loop $AFEBA$ along positive z direction. The magnitude of the magnetic field due to both the loops will be equal.

Therefore direction of resultant magnetic field at $P = \frac{1}{\sqrt{2}}(\hat{i} + \hat{k})$

6. (d) Both arcs are connected in parallel from the battery, then from one arc the magnetic field is upward and from another magnetic field is downward.



Magnetic field at that center due to current arc AB is

$$B_1 = \frac{\mu_0}{4\pi} \times \frac{2\pi I_1}{r} \times \frac{\theta}{2\pi}$$

(Directed upwards)

Magnetic field at the center due to current in ACB arc is

$$B_2 = \frac{\mu_0}{4\pi} \times \frac{2\pi I_2}{r} \times \frac{(2\pi - \theta)}{2\pi}$$

Therefore net magnetic field at the center

$B_{net} = B_1 - B_2$

$$B_{net} = \frac{\mu_0}{4\pi} \times \frac{2\pi I_1}{r} \times \frac{0}{2\pi} - \frac{\mu_0}{4\pi} \times \frac{2\pi I_2}{r} \times \frac{(2\pi - 0)}{2\pi}$$

(Directed upwards)

Also, $I_1 = \frac{V}{R_1} = \frac{V}{\rho l_1 / A} = \frac{VA}{\rho r 0}$

$$I_2 = \frac{V}{R_2} = \frac{V}{\frac{\rho l_2}{A}} = \frac{VA}{\rho r(2\pi - 0)}$$

$$B = \frac{\mu_0}{4\pi}\left[\frac{VA}{\rho r 0} \times \frac{0}{2\pi} - \frac{VA}{\rho r(2\pi - 0)} \times \frac{(2\pi - 0)}{r}\right] = 0$$

7. (a, b) Magnetic field at the plane of the ring is perpendicular to the plane. However, they bend as they move forward

Due to symmetry it depends only on $r = \sqrt{x^2 + y^2}$

but as we approach towards first loop B_1 increases to infinity, so B_1 dominates.

So it would be zero at some point between inner loops and centre.

8. (a, b, d)

(a) At origin, $\vec{B} = 0$ due to two wires if $I_1 = I_2$, as they cancel each other. Thus, $\vec{B}_{net}$ at origin is equal to $\vec{B}$ due to the ring, which is non-zero.

(b) If $I_1 > 0$ and $I_2 < 0$, $\vec{B}$ at origin due to wires will be along $+\hat{k}$ direction and $\vec{B}$ due to the ring is along $-\hat{k}$ direction, and hence, $\vec{B}$ can be zero at the origin.

(c) If $I_1 < 0$ and $I_2 > 0$, $\vec{B}$ at origin due to wires will be along $-\hat{k}$ direction and $\vec{B}$ due to the ring is also along $-\hat{k}$ direction, then, $\vec{B}$ cannot be zero at the origin.

(d) At the center of the ring, $\vec{B}$ due to wires is along x-axis, hence, x-component is only because of the ring, that is, $\vec{B} = \frac{\mu_0 I}{2R}(-\hat{k})$

9. [3] Clearly

$$x_1 = \frac{x_0}{3} \text{ and } x_2 = \frac{2x_0}{3}$$

Case-I

$$B_1 = \frac{\mu_0 I}{2\pi}\left(\frac{1}{x_1} - \frac{1}{x_2}\right)$$

$$B_1 = \frac{\mu_0 I}{2\pi}\left(\frac{3}{x_0} - \frac{3}{2x_0}\right) \Rightarrow B_1 = \frac{3\mu_0 I}{4\pi x_0}$$

Case-II

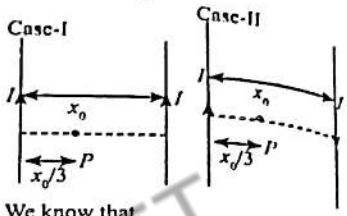
$$B_2 = \frac{\mu_0 I}{2\pi}\left(\frac{1}{x_1} + \frac{1}{x_2}\right)$$

$$B_2 = \frac{9\mu_0 I}{4\pi x_0}$$

We know that, $r = \frac{mu}{qB}$

The ratio radian is $\frac{R_1}{R_2} = \frac{B_2}{B_1}$

On Solving, $\frac{R_1}{R_2} = 3$



10. [5] We know that,

$$B(r) = \frac{\mu_0}{4\pi}\int_c \frac{Idl \times \vec{r}}{r^3}$$

At point P

The magnetic field due to cavity is given by -

$$B_1 = \frac{\mu_0 Ja}{2}$$

The magnetic field due to the cylinder is given by:

$$B_2 = \frac{\mu_0 j\left(\frac{a}{2}\right)^2}{\left(\frac{3a}{2}\right)2\pi} = \frac{\mu_0 ja}{12}$$

Assuming the bigger cylinder to carry a positive current density and

The smaller cylinders carry a negative current density of magnitude each.

The total magnetic field is :

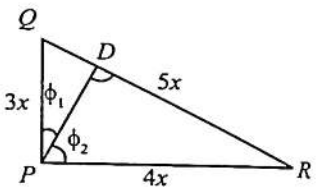
$B = B_1 - B_2$

$$B = \frac{\mu_0 Ja}{2} - \frac{\mu_0 Ja}{12}$$

$$B = \frac{5\mu_0 Ja}{12}$$

$N = 5$

11. [7]



Here, $B_{PQ} = 0$ and $B_{PR} = 0$

$\sin Q = \frac{4}{5}$, $\sin R = \frac{3}{5}$,

Also, angle Q = angle ϕ_2

And angle R = angle ϕ_1

@FAKE_CBSE_JOINEDUNET

$4\pi x_0$

now that, $r = \frac{mu}{qB}$

atio radian is $\frac{R_1}{R_2} = \frac{B_2}{B_1}$

lving, $\frac{R_1}{R_2} = 3$

Case-II

I I x_0 $x_0/3$ P

that,

$\frac{\mu_0}{\pi}\int_c \frac{Idl \times \vec{r}}{r^3}$

etic field due to cavity is

ic field due to the cylinder

$= \frac{\mu_0 ja}{12}$

bigger cylinder to carry
ent density and
linders carry a negative
of magnitude each.
etic field is :

$\frac{Ja}{}$

R

$B_{PR} = 0$

$\frac{3}{5}$,

le ϕ_2

ϕ_1

Hence, $PD = \frac{12x}{5}$

Also we know that,

$B_{QR} = \frac{\mu_0 I}{4\pi PD}(\sin\phi_1 + \sin\phi_2)$

$B_{QR} = \frac{\mu_0 I}{4\pi \times 12x/5}(3/5 + 4/5)$

$B_{QR} = \frac{7\mu_0 I}{48\pi x}$

Hence $k = 7$

12. $B_{net} = \frac{\mu_0 I}{4}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Magnetic field due to coil of radius R_1

$\vec{B}_1 = \frac{1}{2} \times \frac{\mu_0 I}{2R_1}$ outside of the plane

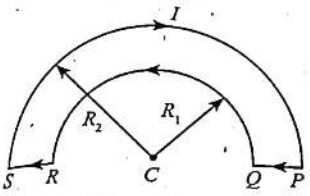
Magnetic field due to coil of radius R_2

$B_2 = \frac{1}{2} \times \frac{\mu_0 I}{2R_2}$ Inside the plane

Therefore, $B \propto \frac{1}{R}$

Hence, $B_{net} = \frac{\mu_0 I}{4R_1} \therefore \frac{\mu_0 I}{4R_2}$

$B_{net} = \frac{\mu_0 I}{4}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$



13. Magnetic field at O due to L and M is zero.

Due to P magnetic field at O is

$B_1 = \frac{1}{2}\left(\frac{\mu_0}{2\pi}\frac{i}{OR}\right)$

$= \frac{(10^{-7})(10)}{0.02} = 5.0 \times 10^{-5}\ T$

(perpendicular to paper outwards)

Similarly, field at O due to Q would be,

$B_2 = \frac{1}{2}\left(\frac{\mu_0}{2\pi}\frac{i}{OS}\right)$

$= \frac{(10^{-7})(10)}{0.02} = 5.0 \times 10^{-5}\ T$

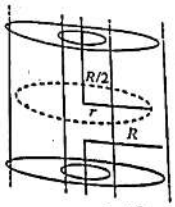
(perpendicular to paper outwards)

Since, both the fields are in same direction, net field will be sum of these two.

$\therefore B_{Net} = B_1 + B_2 = 10^{-4} T$

Direction of field is perpendicular to the paper outwards.

14. (*d*)



$I \rightarrow \pi R^2 - \pi\left(\frac{R}{2}\right)^2$

$I \rightarrow \frac{3}{4}\pi R^2$

$1\,\text{Unit} \rightarrow \frac{4I}{3\pi R^2}$

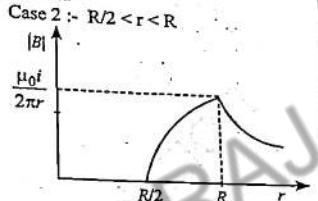
$\therefore$ Hence $= \frac{4I}{3\pi R^2}\left[\pi x^2 - \pi\frac{R^2}{4}\right]$

Case 1 :- r > R

{Result same as infinite wire}

$B = \frac{\mu_0 i}{2\pi r}$

Case 2 :- R/2 < r < R



$\int Bdl = \mu_0 i_{en}$

$B \times 2\pi r = \mu_0 \frac{4i}{3\pi R^2}\left[x^2 - \frac{R^2}{4}\right]$

$\therefore B = \frac{4\mu_0 i}{6R^2\pi^2 r}\left[x^2 - \frac{R^2}{4}\right]$

Case 3 :- $r < R/2$

$B = 0$

15. (*b*) Radius of curvature has to be greater than the width of the magnetic field for the particle to enter the region $x > b$.

Therefore $\frac{mv}{qB} > (b-a)$

Or $v > \frac{qB(b-a)}{m}$

$v_{min} = \frac{qB(b-a)}{m}$

16. (*a*) When the particle is released from rest, it starts to move along the fields due to application of the electric field.

The magnetic force acting on a moving charged particle is given by

$F = q(v \times B)$

Since velocity and magnetic fields are parallel, no magnetic force acts on the particle, hence it continues to move in a straight line along with constant acceleration.

17. (*a*) Force on charged particle

$\vec{F} = q(v \times B)$

For $x = a$ to $2a$

Now $\vec{v} = v_0\,\hat{i}$

$\vec{B} = B_0\hat{j}$

Thus $\vec{F} = qv_0B_0\hat{k}$

Thus the particle will start straying towards the z direction.

For $x = 2a$ to $3a$

$\vec{B} = -B_0\hat{j}$

$\vec{v} = v_0\,\hat{i}$

Thus $\vec{F} = -qv_0B_0\hat{k}$

Thus the particle will start straying towards the $-z$ direction

There won't be any jerks as force always acts perpendicular to particle motion, and acceleration is finite.

Now it starts to stray towards $-z$ direction.

18. (*d*) Because the magnetic field does not do any work, the energy of a charged particle travelling in it remains constant. As a result, kinetic energy is constant, $u = v$.

Initially, the force on the electron will act along the negative y axis.

The electron will move in a clockwise circular motion before exiting the field.

19. (*b*) Electric field can deviate the path of the particle in the shown direction only when it is along negative y-direction.

In the given options $\vec{E}$ is either zero or along x-direction. Hence it is the magnetic field which is really responsible for its curved path. Options (*a*) and (*c*) can't be accepted as the path will be helix in that case (when the velocity vector makes an angle other than 0°, 180° or 90° with the magnetic field, path is a helix) option (*d*) is wrong because in that case component of net force on the particle also comes in k direction which is not acceptable as the particle is moving in x-y plane. Only in option (*b*) the particle can move in x-y plane.

In option (*d*): $\vec{F}_{net} = q\vec{E} + q(\vec{V} \times \vec{B})$

Initial velocity is along x-direction. So let $\vec{v} = v\hat{i}$

@FAKE_CBSE X @RAJ_FAKET

$$\therefore \vec{F}_{net} = qa\hat{i} + q\left[(v\hat{i}) \times (c\hat{k} + b\hat{j})\right]$$

$$= qa\hat{i} - qvc\hat{j} + qvb\hat{k}$$

In option (b)

$$\vec{F}_{net} = q(a\hat{i}) + q\left[(v\hat{i}) \times (c\hat{k} + a\hat{i})\right] = qa\hat{i} - qvc\hat{j}]$$

20. (c) As gas is subjected to the Electric field, Positive ions will start to move along the $+x$ direction and negative ions along the $-x$ direction, which implies that the current will then be along the $+x$ direction. Then using Fleming's left-hand rule, the force will be along $-Y$ direction; they will get deflected towards $-Y$ direction.

21. (b) When a charged particle is moving at right angle to the magnetic field, then a force acts on it which behaves as a centripetal force and moves the particle in a circular path.

But, $r = \frac{p}{qB}$

Radius of B is less than the radius of A.

$\therefore r_B < r_A$

$\therefore p_B < p_A$ (since q and B are same for both the particle)

$\Rightarrow m_B v_B < m_A v_A$

22. (a) The centripetal force is provided by the magnetic force

$$\frac{mv^2}{r} = qvB \Rightarrow \frac{mv}{r} = qB$$

$$\Rightarrow r = \frac{mv}{qB} = \frac{p}{qB}[\because p = mv]$$

But $KE = \frac{p^2}{2m} \Rightarrow p = \sqrt{2mKE}$

Here, KE and B are same for the three particles

$$\therefore r \propto \frac{\sqrt{m}}{q}$$

$$\therefore r_p : r_d : r_\alpha = \frac{\sqrt{1}}{2} : \frac{\sqrt{2}}{1} : \frac{\sqrt{4}}{2} = 1 : \sqrt{2} : 1$$

$$\Rightarrow r_\alpha = r_p < r_d$$

23. (c) Radius of circular path traversed by a particle given by;

$$r = \frac{mv}{qB}$$

Kinetic energy $E_k = \frac{1}{2}mv^2 = eV$

$$r = \frac{\sqrt{m^2v^2}}{qB} = \frac{\sqrt{2mE_k}}{qB} \Rightarrow r = \frac{\sqrt{2meV}}{qB}$$

Now, $m \propto r^2$

Therefore the ratio of masses X to Y

$$\frac{M_x}{M_y} = \left[\frac{R_1}{R_2}\right]^2$$

24. (a, d) The charge carriers in a metallic strip are electrons. The electrons moves in a direction opposite to the current flow with a drift velocity given by,

$$v_d = \frac{I}{neA} = \frac{I}{new'd}$$

Where n is the number density of the electrons (number of electrons per unit volume), e is the electronic charge, and $A = wd$ is the cross-sectional area of the strip. The electrons move with velocity $\vec{v}_d = -v_d\hat{i}$ in a uniform magnetic field $\vec{B} = B\hat{j}$

Thus, magnetic force on the moving electrons is,

$$\vec{F}_m = q\vec{v}_d \times \vec{B} = (-e)(-v_d\hat{i}) \times B\hat{j} = ev_dB\hat{k}$$

$$= \frac{IB}{nwd}\hat{k}$$

Note that an electron has a negative charge $q = -e$. From the above equation, the electrons start moving towards the face $PQRS$ leading to the negative potential at this face. This potential establishes an electric field in a direction from K to M. If V is the potential difference between these faces then electric field is $\vec{E} = \frac{V}{w}\hat{k}$. The electric force on the electrons is,

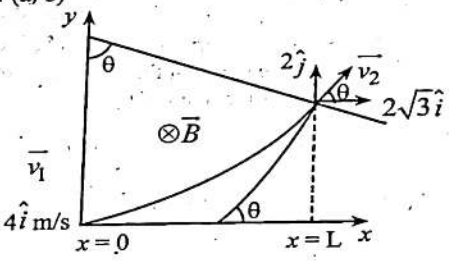
$$\vec{F}_e = q\vec{E} = (-e)\frac{V}{w}\hat{k} = -\frac{eV}{w}\hat{k}$$

The accumulation of electrons on face PQRS continues till the net force on the electrons becomes zero (equilibrium condition). Use equations to get the potential difference in equilibrium condition,

$$V = \frac{IB}{ned'}$$

From this equation, V depends on d and not on w. Thus, if $d_1 = 2d_2$, then $V_2 = 2V_1$ and if $d_1 = d_2$, then $V_2 = V_1$.

25. (a, c)



$$\tan\theta = \frac{2}{2\sqrt{3}} = \frac{1}{\sqrt{3}}$$

$$\theta = 30° = \frac{\pi}{6}$$

Time period of circular motion $T = \frac{2\pi M}{QB}$

Time spent inside the magnetic field is

$$t = \frac{\pi}{6} \times \frac{T}{2\pi} = \frac{\frac{\pi}{6}}{2\pi} \times \frac{2\pi M}{QB} = \frac{\pi M}{6QB}$$

Give, $t = 10$ ms $= 10 \times 10^{-3}$ s

$$\therefore \frac{\pi M}{6QB} = 10 \times 10^{-3}$$

$$\therefore B = \frac{50\pi M}{3Q}$$

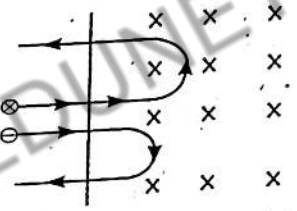
As seen from the figure, $\vec{u} = 4\hat{i}$

Since the particle bends upward, B has to be in $\hat{k}$ – direction since {F} is in {$\hat{j}$} direction.

26. (b, d) $r = \frac{mv}{Bq}$ or $r \propto m$

$r_e < r_p$ as $m_e < m_p$

Further, T = $T = \frac{2\pi m}{Bq}$ or $T \propto m$



$$\therefore T_e < T_p, t_e = \frac{T_e}{2} \text{ and } t_p = \frac{T_p}{2}$$

or $t_e < t_p$

27. (c, d) If $\theta = 0°$ then due to magnetic force path is circular but due to force qE_0 ($\uparrow$)q will have accelerated motion along y-axis. So combined path of will be a helical path with variable pitch so (a) and (b) are wrong.

If $\theta = 10°$, then due to , path is circular and due to qE_0 and $v\sin\theta$, q has accelerated motion along y-axis so combined path is a helical path with variable pitch (c) is correct.

If $\theta = 90°$ then $F_B = 0$ and due to motion is accelerated along y-axis (d).

28. (a, c, d) As the particle enters region II, it will have a portion of circular path in this Region.

$$r = \frac{mv}{qB}$$

If the width of the region is less than r, the particle will enter region III.

$$\therefore \frac{mv}{qB} > l \Rightarrow v > \frac{qBl}{m}$$

The path length of the particle in region II will be maximum

When $v = \frac{qlB}{m}$

@FAKE_CBSE_KORAJ_EDUNET

When, time spent in the region II is

$t = \frac{T}{2} = \frac{2\pi m}{2qB} = \frac{\pi m}{qB}$

Time is independent of speed.

29. (a,b,d) In going from to increase in kinetic energy

$\frac{1}{2}m(2v)^2 - \frac{1}{2}mv^2 = \frac{1}{2}m(3v^2)$

= Work done by electric field

or, $3/2\ mv^2 = Eq \times 2a \Rightarrow E = \frac{3mv^2}{4qa}$

The rate of work done by E at $P = F.v$

$= qEv = q\left(\frac{3mv^2}{4qa}\right)v = \frac{3mv^3}{4a}$

At Q, $\vec{v}$ is perpendicular to $\vec{E}$ and $\vec{B}$, therefore no work done by the either field.

30. (a,b,d) (i) When no field is present $E = 0$, $B = 0$, the proton experiences no force. Thus it moves with a constant velocity.

(ii) When $E = 0$ and, $B \neq 0$, then there will be a probability that proton may move parallel to magnetic field. In this situation, there will be no force acting on proton.

(iii) When both fields are present $E \neq 0$, $B \neq 0$, then let E, B and v may be mutually perpendicular to each other. In this case, the electric and magnetic forces acting on the proton may be equal and opposite. Thus, there will be no resultant force on the proton.

31. (c) For a particle to move in negative y-direction, either its velocity must be in negative y-direction (if initial velocity $\neq 0$) and force should be parallel to velocity or it must experience a net force in negative y-direction only (if initial velocity = 0)

32. (a) $\vec{F}_{net} = \vec{F}_e + \vec{F}_B = q\vec{E} + q\vec{v} \times \vec{B}$

For particle to move in straight line with constant velocity,

$\vec{F}_{net} = 0$

$\therefore\ q\vec{E} + q\vec{v} \times \vec{B} = 0$ or $\vec{E} = \vec{B} \times \vec{v}$

33. (c) For path to be helical with axis along positive z -direction, particle should experience a centripetal acceleration in xy-plane.

For the given set of options, only option (c) satisfy the condition. Path is helical with increasing pitch.

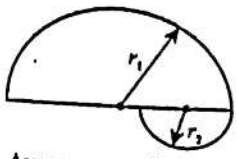
34. [4] $r_\alpha = \frac{\sqrt{2m_\alpha q_\alpha V}}{q_\alpha B}$

$r_s = \frac{\sqrt{2m_s q_s V}}{q_s B}$

$\frac{r_s}{r_\alpha} = \sqrt{\frac{m_s}{q_s}\frac{q_\alpha}{m_\alpha}} = \sqrt{\left(\frac{32}{1}\right)\left(\frac{2}{4}\right)}$

$\frac{r_s}{r_\alpha} = 4$

35. [2]



Average speed along the x-axis,

$\langle v_x \rangle = \frac{\int |\vec{v}_x| dt}{\int dt} = \frac{d_1 + d_2}{t_1 + t_2}$ ...(1)

We also have, $r_1 = \frac{mv}{qB_1}, r_2 = \frac{mv}{qB_2}$

Since, $B_1 = \frac{B_2}{4}, r_1 = 4r_2$ ...(2)

Time in $B_1 \Rightarrow \frac{\pi m}{qB_1} = t_1$

Time in $B_2 \Rightarrow \frac{\pi m}{qB_2} = t_2$

Total distance along x-axis $= d_1 + d_2$

$= 2r_1 + 2r_2 = 2(r_1 + r_2) = 2(5r_2) = 10r_2$

Total time $= T = t_1 + t_2 = 5t_2$

Therefore, average speed

$= \frac{10r_2}{5t_2} = \frac{10 \times mv_0 / qB_2}{5 \times \pi m / qB_2}$

{Given $v_0 = \pi$ m/s}

$\therefore\ v = 2$ m/s

36. [14] Radius of circular path, $r = \frac{mv}{Bq} = \frac{p}{Bq}$

$= \frac{\sqrt{2Km}}{Bq}$

Since, radius in both cases must be the same, thus,

$\frac{\sqrt{2K_\alpha m_\alpha}}{Bq_\alpha} = \frac{\sqrt{2K_d m_d}}{Bq_d}$

$\frac{q_d}{q_\alpha} = \frac{e}{2e} = \frac{1}{2}$

$\frac{m_\alpha}{m_d} = \frac{4}{2} = 2$

So, $K_d = (2.3)^2\left(\frac{q_d}{q_\alpha}\right)^2\left(\frac{m_\alpha}{m_d}\right)K_\alpha$

$= (2.3)^2\left(\frac{1}{2}\right)^2(2)(5.3)$

$K_d = 14\ MeV$

37. According to Fleming's left hand rule, the force on electrons will be towards right (D). Also, by the same rule we find that the force on proton and α-particle is towards left. Now since the magnetic force will behave as centripetal force, therefore

$\rightarrow (mv^2)/(r) = qvB$

$\rightarrow (mv)/(qB) = r$

Since velocity is same for all.

Therefore, radius of path is proportional to the ratio of m/q

this ratio is more for alpha particle than proton i.e alpha particle will have greater radius, so the alpha particle follows track B.

38. Since it is a metallic block, the charge carriers are electrons, and so if the current is flowing in the $+x$-axis, then the electrons are moving along the $-x$-axis.

i.e.,

$\vec{v} = -v\hat{i}$

And the magnetic field is, $\vec{B} = B\hat{j}$

So, $\vec{F} = q(\vec{v} \times \vec{B}) = (-e)(-v\hat{i} \times B\hat{j}) = evB\hat{k}$

Since, force on electrons is acting towards the $ABCD$ face, the electrons will accumulate there and hence, it would have lower potential.

39. [False] Radius, $r = mv/qB$

Since both electron and proton have same charge

Mass is different for proton and electron so the radius will be different

Hence false.

40. [False] To form a circle a particle should be tangential to the magnetic field lines.

So here it won't from circular path hence false.

41. [True] The magnetic field can change the velocity but not the speed and hence the kinetic energy remains constant. So this is true.

42. Kinetic energy of electron

$K = \frac{1}{2}mv^2 = 2\ keV$

Speed of electron

$v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2 \times 2 \times 1.6 \times 10^{-16}}{9.1 \times 10^{-31}}} ms^{-1}$

$= 2.65 \times 10^7\ ms^{-1}$

Since the velocity $\vec{v}$ of the electron make an angle of $\theta = 60°$

With the magnetic field $\vec{B}$ the path wi be a helix.

So the particle will hit S if G_s

p = pitch of helix $= \frac{2\pi m}{qB}v\cos\theta$

$\Rightarrow GS = \frac{n2\pi mv\cos\theta}{qB}$

$\Rightarrow B = \frac{n2\pi mv\cos\theta}{q(GS)}$

@FAKE_CBSE_X @RAJ_DUNEFT

But for B to be minimum, $n = 1$

$$B_{min} = \frac{2\pi mv\cos\theta}{q(GS)}$$

Substituting the value, we have

$$B_{min} = \frac{(2\pi)(9.1\times10^{-31})(2.67\times10^{7})\left(\frac{1}{2}\right)}{(1.6\times10^{-19})(0.1)}$$

$$B_{min} = 4.75\times10^{-3}\ T$$

43. The force on electron will be toward the left plane due to electric field and will be equal to $F_e = eE$

For the electron to move undeflected between the plates, there should be a force (magnetic) which is equal to the electric force and opposite in direction to electric force. So the force should be directed toward the right as the electric force is toward the left. On applying Fleming's left hand rule, we get that the magnetic field should be directed perpendicular to the plane of paper and inwards. Therefore, Force due to electric field = Force due to magnetic field

$$eE = evB\left[\because E = \frac{v}{d}\right]$$

$$B = \frac{E}{v} = \frac{V/d}{v}$$

Where, V = potential difference between the plates, and d = distance between the plates

$$B = \frac{\frac{600}{3}\times10^{-3}}{2\times10^{6}} = \frac{600}{3\times10^{-3}\times2\times10^{6}}$$

$$\Rightarrow B = 0.1T$$

44. The particle will be a $2e$ helium nucleus with a mass of $4u$.

The proton is a hydrogen atom.

$1e$ charge and $1u$ mass

The radius of a charged particle's circle in a magnetic field will be $r = \frac{mv}{qB}$

Now, $r = \frac{\sqrt{2Km}}{qB}$

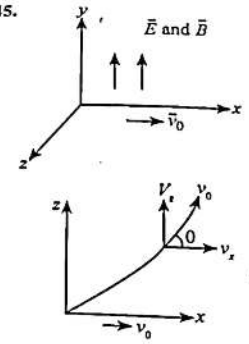
Also, $K \rightarrow$ kinetic energy $= qv$

$$\therefore r = \frac{\sqrt{2qvm}}{qB} = \sqrt{\frac{2vm}{qB^2}}$$

$$\therefore r \propto \sqrt{\frac{m}{q}}$$

$$\therefore \frac{r_p}{r_\alpha} = \sqrt{\frac{m_p}{m_\alpha}\times\frac{q_\alpha}{q_p}} = \sqrt{\frac{m}{4m}\times\frac{2e}{e}} = \frac{1}{\sqrt{2}}$$

45.



$$\hat{i} = \frac{\vec{v}_0}{v_0},\ \hat{j} = \frac{\vec{E}}{E} = \frac{\vec{B}}{B},\ \hat{k} = \frac{\vec{v}_0\times B_0}{v_0 B}$$

Force due to the electric field will be along the y-axis. Magnetic force will not affect the motion of charged particles in the direction of the electric field (or y-axis) so.

$$a_y = \frac{F_e}{m} = \frac{qE}{m},\ v_y = a_y t = \frac{qE}{m}T \quad ...(i)$$

The charged particle under the action of magnetic field describes a circle in x–z plane (perpendicular to B) with:

$$T = \frac{2\pi m}{Bq} \text{ or } \omega = \frac{2\pi}{T} = \frac{qB}{m}$$

Initially ($t = 0$) velocity was along the x-axis. Therefore, magnetic force $\left(\vec{F}_m\right)$ will be along positive z-axis, as $\vec{F}_m = q\left(\vec{v}\times\vec{B}\right)$.

Let this force make an angle θ with x-axis at time t, then $\theta = \omega t$.

Therefore,

$$v_x = v_0\cos\omega t = v_0\cos\left(\frac{qB}{m}t\right) \quad ...(ii)$$

$$v_z = v_0\sin\omega t = v_0\sin\left(\frac{qB}{m}t\right) \quad ...(iii)$$

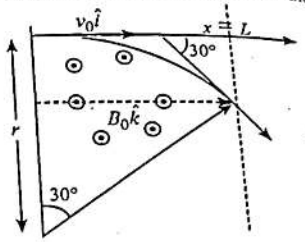
From the equation (i), (ii) and (iii) we can write,

$$v = v_x\hat{i} + v_y\hat{j} + v_z\hat{k}$$

$$v = \cos\left(\frac{qB}{m}t\right)(v_0) + \left(\frac{q}{m}t\right)(E) + \sin\left(\frac{qB}{m}t\right)\left(\frac{v_0\times B}{B}\right)$$

Thus, the path of the particle would be a helix of increasing pitch. The axis of the helix will be along the y-axis.

46. As the initial velocity of the particle is perpendicular to the field. The particle will move along the arc of a circle as shown figure. If r is the radius of the circle then



$$\frac{mv_0^2}{r} = qv_0B_0$$

$$r = \frac{mv_0}{qB_0}$$

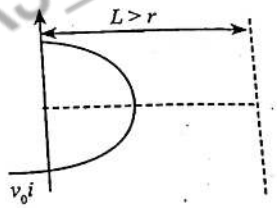
Also from geometry,

$L = r\sin30°$

$r = 2L$

$$L = \frac{r}{2} \Rightarrow L = \frac{1}{2}\frac{mv_0}{qB_0}$$

(*b*) In this case length of magnetic field is greater then the radius of particle path, Hence particle will complete a semi-circular path and emerge with velocity $v_0\hat{i}$ as shown in fig below.



The time spent by the particle in the magnetic field,

$$T = \frac{\pi r}{v_0} = \frac{\pi m}{qB_0}$$

47. (*a*) $d = a\cos60°$

Magnetic field at Point P due to straight wire $MN = B_{MN}$.

Therefore,

$$B_{MN} = \frac{\mu_0 I}{4\pi d}\left(\sin60° + \sin60°\right)$$

$$= \frac{\mu_0 I}{4\pi a\cos60°}\left(2\sin60°\right) = \frac{\mu_0 I}{4\pi a}\left(2\sqrt{3}\right)$$

(into the paper)

Circular arc MON $= B_{MON} = \frac{\theta}{2\pi}\frac{\mu_0 I}{2a}$

$$= \frac{\mu_0 I}{4\pi a}\times\frac{2\pi}{3}$$ (out of the paper)

$\therefore B_{net} = \frac{0.1\,l\mu_0 t}{a}k$

Now, velocity of particle can

as, $v = v\cos60°\,\hat{i} + v\sin60°$

$= \frac{v}{2}\hat{i} + \frac{\sqrt{3}v}{2}\hat{j}$

Magnetic force

$F_e = Q(v\times B) = \frac{0.1\,l\mu_0 lQv}{2a}\hat{j}$

$\therefore$ Instantaneous accele

$a = \frac{F_m}{m} = \frac{0.1\,l\mu_0 lQ}{2am}$

(*b*) In uniform magnetic current loop is zero. F dipole moment of the

$M = (lA)\ \hat{k}$

Here, A is the area of

$A = \frac{1}{3}(\pi a^2) - \frac{1}{2}[2\times$

$= \frac{\pi a^2}{3} - \frac{a^2}{2}\sin120°$

$\therefore M = (0.61\ la^2)$

Given, $B = B\,\hat{i}$

$\Rightarrow \tau = M\times B = ($

48. (*a*) When a charged at an angle to component of field is $v\cos\theta$, velocity perper $\sin\theta$, resulting a circle with a

$r = \frac{m(v\sin\theta)}{qB}$

$= \frac{(1.67\times10^{-}$

$= \frac{1.}{}$

$= \frac{(1.67\times10^{-}$

$= \frac{1.}{}$

(*b*) Time peri

$T = \frac{2\pi}{v\sin}$

$= \frac{2\pi\times}{4\times1}$

@FAKE_CBSE_X_@RAJ_LINE

$= \frac{\mu_0 I}{4\pi a}(2\sqrt{3}) - \frac{\mu_0 I}{4\pi a} \times \frac{2\pi}{3} = \frac{\mu_0 I}{2\pi a}\left(\sqrt{3} - \frac{\pi}{3}\right)$

$\therefore B_{net} = \frac{0.11\mu_0 I}{a}\hat{k}$

Now, velocity of particle can be written as,

$v = v\cos 60°\ \hat{i} + v \sin 60°\ \hat{j}$

$= \frac{v}{2}\hat{i} + \frac{\sqrt{3}v}{2}\hat{j}$

Magnetic force

$F_m = Q(v \times B) = \frac{0.11\mu_0 IQv}{2a}\hat{j} - \frac{0.11\sqrt{3}\mu_0 IQv}{2a}\hat{i}$

$\therefore$ Instantaneous acceleration

$$a = \frac{F_m}{m} = \frac{0.11\mu_0 IQv}{2am}(\hat{j} - \sqrt{3}i)$$

(*b*) In uniform magnetic field, field on a current loop is zero. Further, magnetic dipole moment of the loop will be.

$M = (IA)\ \hat{k}$

Here, A is the area of the loop.

$A = \frac{1}{3}(\pi a^2) - \frac{1}{2}[2 \times a\sin 60°][a\cos 60°]$

$= \frac{\pi a^2}{3} - \frac{a^2}{2}\sin 120° = 0.61a^2$

$\therefore M = (0.61\ Ia^2)\ \hat{k}$

Given, $B = B\hat{i}$

$\Rightarrow \tau = M \times B = (0.61\ Ia^2B)\ \hat{j}$

48. (*a*) When a charged particle is projected at an angle to a magnetic field, the component of velocity parallel to the field is $v\cos\theta$, while the component of velocity perpendicular to the field is $v\sin\theta$, resulting in the particle moving in a circle with a radius of radius.

$r = \frac{m(v\sin\theta)}{qB}$

$= \frac{(1.67\times10^{-27})\times(4\times10^5\sin 60°)}{1.6\times10^{-19}\times0.3}$

$= \frac{(1.67\times10^{-27})\times\left(4\times10^5\times\frac{\sqrt{3}}{2}\right)}{1.6\times10^{-19}\times0.3} = \frac{2\times10^{-2}}{\sqrt{3}}$

(*b*) Time period:

$T = \frac{2\pi r}{v\sin\theta} = \frac{2\pi\times\frac{2\times10^{-2}}{\sqrt{3}}}{4\times10^5\times\sin 60°}$

$= \frac{2\pi\times\frac{2\times10^{-2}}{\sqrt{3}}}{4\times10^5\times\frac{\sqrt{3}}{2}} = \frac{2\pi}{3}\times10^{-7}$

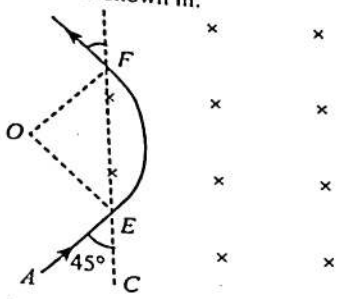
Pitch: $p = v\cos\theta T$

$= (4\times10^5)\times\cos 60°\times\frac{2\pi}{1}\times10^{-7} = \frac{4\pi}{3}\times10^{-2}$

$= 4.35\times10^{-2}$ m

49. (*a*) As the particle enters the magnetic field, it will travel in a circular path. The center will be on the line which is perpendicular to its velocity and the radius r will be $\frac{mv}{qB}$

The direction of the force $q(\vec{v}\times\vec{B})$ shows that the center will be outside the field as shown in.



As $\angle AEO = 90°$

(as AE is tangent and OE is radius) and,

$\angle AEO = 45°$

We have $\angle OEF = 45°$.

As $OE = OF$ (they are radii of the circular arc),

$\angle OFE = \angle OEF = 45°$.

Also, OF is perpendicular to the velocity of the particle at F, so that $\theta = 45°$ from triangle OEF,

$EF = 2.OE\cos\angle OEF = 2.\ \frac{mv}{qB}\cdot\frac{1}{\sqrt{2}}$

$\therefore EF = 2\times\frac{1.6\times10^{-27}\times10^7}{1.6\times10^{-19}\times1}\times\frac{1}{\sqrt{2}}$

$\therefore\ EF = 0.41$ m $= 14$ cm.

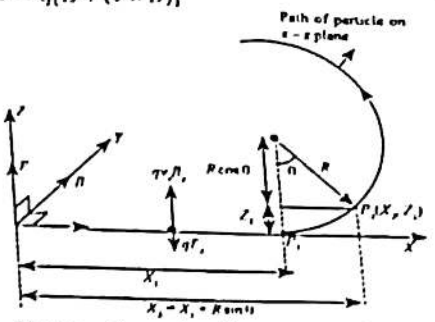
(*b*) If the magnetic field is coming out of the paper, the direction of the force $q(\vec{v}\times\vec{B})$ shown in figure Again $\angle AEO = 90°$ giving $\angle OEF = \angle OFE = 45°$. Thus, the angle $EOF = 90°$

The particle describes three fourths of the complete circle inside the field. As the speed v is uniform, the time spent in the magnetic field will be

$T = \frac{3}{4}\times(2\pi r)(v) = (3\pi mv)(2vqB)\frac{3\pi m}{2qB}$

$= \frac{3\times3.14\times1,6\times10^{-27}kg}{2\times1.6\times10^{-19}\ C\times1.0T} = 4.7\times10^{-8}\ s$

50. In presence of simultaneous electric and magnetic field, the Lorentz force is $\vec{F} = q[\vec{E} + (\vec{v}\times\vec{B})]$



Under action of uniform magnetic field only, the particle performs uniform circular motion of radius $r = mv/qB$

Let I, J and k be unit vector along the positive directions of x, y and z axes.

Q = charge on the particle $= 1.6\times10^{-19}$ C, v = velocity of the charged particle $= (1.28\times10^6)$ m/s $\hat{i}$, Vector E = electric field intensity $= (-102.4\times10^3\ V/m)\ \hat{k}$

Vector B = magnetic induction of the magnetic field $= (8\times10^{-2}\ T)\ \hat{j}$

$\therefore$ Vector F_e = electric force on the charge

$F_e = qE = 1.6\times10^{-19}\ C\times(-102.4\times10^3\ V/m)\ \hat{k}$

$F_e = 163.84\times10^{-16}\ N(-\hat{k})$

F_m = magnetic force on the charge $= qv\times B$

$F_m = 1.6\times10^{-19}\ C\ [(1.28\times10^6)m/s\times(8\times10^{-2})]\ (\hat{i}\times\hat{j})$

$F_m = 163.84\times10^{-16}\ \hat{k}$

The two forces are along z-axis and equal, opposite and collinear.

The net force on the charge is zero and hence the particle does not get deflection and continues to travel along x-axis.

(*a*) At time $t = 5\times10^{-6}$ s

$x = (5\times10^{-6}\ s)\times(1.28\times10^6)$m/s $= 6.4$ m

$\therefore$ Coordinates of the particle $= (6.4\text{ m}, 0, 0)$

(*b*) When the electric field is switched off, the particle is in the uniform magnetic field perpendicular to its velocity only and has a uniform circular motion in the x–z plane (i.e. the plane of velocity and magnetic force), anticlockwise as seen along $+y$-axis.

Now, $\frac{mv^2}{r} = qvB$

Where r is the radius of the circle.

Hence, $r = \frac{mv}{qB}$

$= \frac{1\times10^{-26}\ kg\times1.28\times10^6\ m/s}{1.6\times10^{-19}C\times8\times10^{-2}\ T} = 1$

@TAKE_CBSE_R@RAJ_TOMER

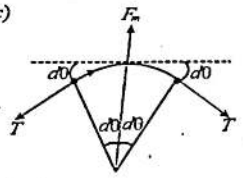
The length of the arc traced by the particle in 7.45×10^{-6} s

$x' = (v)(T) = (1.28 \times 10^6 \text{ m/s})(7.45 \times 10^{-6} \text{ s}) = 3.136$ m

$\Rightarrow \pi m = 1/2$ circumference.

$\therefore$ The particle has the coordinates (6.4,0,2 m) as (x, y, z).

51. *(c)*



$L = 2\pi\rho$

$\therefore P = L/2\pi$

cos components are cancelled.

$2T\sin(d\theta) = Fm$

For small angles, $\sin(d\theta) \approx d\theta$

$2T(d\theta) = I(dL)B\sin 90° = I(2R \cdot d\theta) \cdot B$

$T = IRB = \frac{ILB}{2\pi}$

52. *(b)* We know the magnetic field due to a long current carrying wire is given as

$$B = \frac{\mu_0 I}{2\pi r} \Rightarrow B \propto \frac{1}{r}$$

Magnetic field in between the two conductors will be in opposite direction using right hand thumb rule, the magnetic field due to left wire will be in the $\hat{j}$ direction while due to the right wire in $\hat{j}$ direction

Magnetic field at a distance x from the left wire is given as

$$B = \frac{\mu_0 I}{2\pi x}\hat{j} + \frac{\mu_0 I}{2\pi(2d-x)}\left(-\hat{j}\right)$$

$$= \frac{\mu_0 I}{2\pi}\left[\frac{1}{x} - \frac{1}{(2d-x)}\right]\hat{j}$$

At $x = d$, $B = 0$

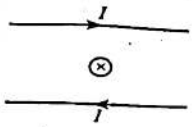
At $x > d$, B is along $-\hat{j}$

At $x < d$, B is along $\hat{j}$

On the left side of the left conductor, magnetic field due to the both the conductors will add up and will be along the $\hat{j}$ direction.

On the right side of the right conductor, magnetic field due to the both the conductors will add and will be along $\hat{j}$ direction.

53. *(d)* Net magnetic field due to the wires will be downward.



Now, angle between $\vec{v}$ and $\vec{B}$ is 180°, therefore,

Magnetic force, $\vec{F} = q(\vec{v} \times \vec{B}) = qvB\sin 0$

$= qvB\sin 180° = 0$

54. *(b)* Given that,

Current in both the wires is the same.

Lets say

Current in first wire is I_1 and

Current in second wire is I_2

According to the question, $I_1 = I_2 = I$

We know

$$\therefore F = \frac{\mu_0 I^2 l}{2\pi b}$$

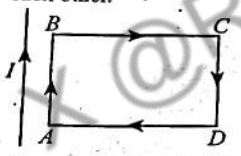
The force per unit length is $F = \frac{\mu_0 i^2}{2\pi b}$

55. *(c)* The current in wire AB and long wire are in the same direction,

Hence, wire AB and long wire attract each other.

The current in wire CD and long wire are in opposite direction,

Hence, wire CD and long wire repel each other.



Forces on DA and BC are equal and opposite to each other.

Since the wire AB is nearer to the long wire, force of attraction towards the long wire will be more. Hence, the loop will move towards the wire.

56. *(c)* Magnetic force on a current carrying loop in uniform magnetic field is zero

57. *(b, c)* While entering, $x < L$,

$$F = BIL = \frac{vB^2L^2}{R}$$

$$\frac{F}{m} = \frac{vB^2L^2}{mR} = kv = -v\frac{dv}{dx}$$

$$\int_{v_0}^{v} dv = -k\int_0^x dx$$

$$v = v_0 - kx$$

$$f = \frac{B^2L^2}{R}(v_0 - kx) = \alpha - \beta x$$

$$I = \frac{BL}{R}(v_0 - kx) = I_0 - \gamma x$$

[i decreases from $x = 0$ to $x = L$ I become zero from $x = L$ to $x = 3L$ I change direction and decreases from $x = 3L$ to $x = 4L$]. These characteristics are shown in graph *(b)* and *(c)* only.

58. *(a, b, c)* The vector sum of all current element in wires not parallel to x-axis will lead to the resultant current element of length R and current along x-axis. Total length of current element:

$dl = 2(L + R)\hat{x}$

$\vec{F} = I(2(L + R)\hat{x}) \times \vec{B}$

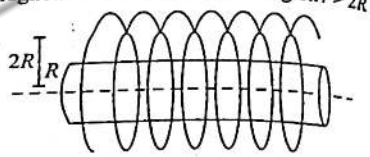
If B along z then F will be along $-\hat{y}$ and will be proportional to $(L + R)$ If $\vec{B}$ along $\vec{x}$ then $F = 0$ since the vector product is zero.

If $\vec{B}$ along $\hat{y}$ then F will be along z and will be prop to $(L + R)$

If $\vec{B}$ along then F will be along $-\hat{y}$ and will not be equal to 0.

59. *(a,d)* Magnetic field is non zero in region $0 < r < R$

Magnetic field is non- zero in region $r > 2R$



60. *(a, c)* $F_{BA} = 0$, because magnetic lines are parallel to this wire.

$F_{CD} = 0$, because magnetic lines are anti-parallel to this wire.

F_{CB} is perpendicular to paper outwards and F_{AD} is perpendicular to paper inwards. These two forces (although calculated by integration) cancel each other but produce a torque which tend to rotate the loop in clockwise direction about an axis OO'.

61. *(A-q,r B-p C-q,r D-q)*

We can find the direction of magnetic field at P due to a wire by the corkscrew rule, and the direction of force on a wire due to another is calculated by the direction of cross product of current and direction of magnetic field.

$F = il \times \vec{B}$

Option $(A) - (q)(r)$

By thumb rule, the magnetic field lines at P due to both wires are in opposite directions. and since it's midpoint, they're equal and opposite by symmetry, thus, the resultant field is zero.

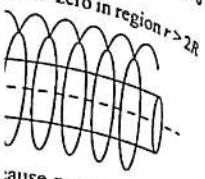
@FAKE_CBSE_X @RAJEEDUNET

$\ldots) = I_0 - \gamma x$

ases from $x = 0$ to $x = L$, I become
$n\ x = L$ to $x = 3L$, I change direction
eases from $x = 3L$ to $x = 4L$]. These
istics are shown in graph (*b*) and

The vector sum of all current
wires not parallel to x-axis will
e resultant current element of
nd current along x-axis. Total
urrent element:
$R)\hat{x}$
$\cdot R)\hat{x}) \times \vec{B}$

then F will be along $-\hat{y}$ and
ortional to $(L + R)$ If $\vec{B}$ along
0 since the vector product is
; then F will be along z and
$(L + R)$
en F will be along $-\hat{y}$ and
al to 0.
field is non zero in region 0
; non- zero in region $r > 2R$



ause magnetic lines are
:.
nagnetic lines are anti-
:.
lar to paper outwards
cular to paper inwards.
although calculated by
ach other but produce
to rotate the loop in
bout an axis OO'.
$-q$)
ion of magnetic field
the corkscrew rule,
force on a wire due
d by the direction of
nt and direction of

netic field lines at P
pposite directions.
they're equal and
hus, the resultant

The direction of force on each wire is towards each other, as it can be seen from the above equation, hence they attract each other.

Option B – (p)

By thumb rule (apply on infinitesimal parts for the sense of direction of magnetic field), the magnetic field lines at P due to both wires are in the same direction. The wires neither attract nor repel.

Option C – (q) (r)

By the thumb rule, the magnetic field lines at P due to both wires are in opposite directions, and since it's midpoint, they're equal and opposite by symmetry, thus, the resultant field is zero.

The direction of force on each wire is towards each other, as it can be seen from the above equation, hence they attract each other.

Option D – (q)

By thumb rule, the magnetic field lines at P due to both wires are in opposite directions and since the radius is different, the resultant field is non-zero and in the opposite direction.

62. Net force is on an imaginary wire FA having current I from F to A.

$$F = I\left[\left(L\hat{i}\right)\times\left(B\hat{j}\right)\right] = ILB\hat{k}$$

$\because$ Magnitude of force is ILB and direction of force is positive z.

Hints

(*i*) Assume equal and opposite currents in wires AF and then FA.

(*ii*) Net force on a current carrying loop in uniform magnetic field

63. Let R be the radius of circle. Then,

$$2\pi R = L \text{ or } R = \frac{L}{2\pi}$$

$$M = iA = i\pi R^2 = \frac{L^2 i}{4\pi}$$

64. [True] A current-carrying coil is a magnetic dipole.

In a uniform magnetic field,

The net force on a magnetic dipole is zero.

So given statement is true

65. The current-carrying wire AB experiences a force due to the magnetic field created by wire CD.

Find the equation of motion of wire AB.

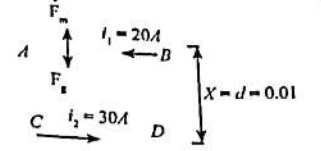
If the force acting on wire AB is restoring in nature and directly proportional to its displacement from the equilibrium position, then we compare the equation of acceleration with the standard differential equation of SHM.

Then time period of oscillation is given by

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Let m be the mass per unit length of wire AB.

At a height x about the wire AB will be given by



$$F_m = \frac{\mu_0 i_1 i_2}{2\pi x}(\text{upwards}) \qquad \ldots(i)$$

Wt. per unit of wire AB is (downwards) At, wire in equilibrium.

i.e., $F_m = F_g \Rightarrow \frac{\mu_0 i_1 i_2}{2\pi d} = mg$

$$\Rightarrow \frac{\mu_0 i_1 i_2}{2\pi d^2} = \frac{mg}{d} \qquad \ldots(ii)$$

When AB is deeded, x decreases; therefore, F_m will increase, and F_g remains the same. Let AB is displaced by dx downwards. Differentiating equation (*i*) w.r. t.x, we get

$$dF_m = -\frac{\mu_0 i_1 i_2}{2\pi x^2}dx \qquad \ldots(iii)$$

i.e., restoring force,

$F = dF_m \propto -dx$

Hence the motion of wire is simple harmonic. From equations (*ii*) and (*iii*), we can write.

$$dF_m = -\left(\frac{mg}{d}\right)\cdot dx \qquad (x = d)$$

$\therefore$ Acceleration of wire, $a = -\left(\frac{g}{d}\right)\cdot dx$

Hence period of oscillations

$$T = 2\pi\sqrt{\frac{dx}{a}} = 2\pi\sqrt{\left|\frac{\text{disp.}}{\text{acc.}}\right|}$$

$$\Rightarrow T = 2\pi\sqrt{d/g}$$

$$T = 2\pi\frac{\sqrt{0.01}}{9.8} \Rightarrow T = 0.2\text{s}$$

66. (*a*) To calculate the magnetic field at the center of the center, let us consider two semi circles of radii $r_1 = 0.8$ m and $r_2 = 0.12$ m

Since, current is flowing in the same direction. The magnetic field created by circular arcs will be in same direction.

$$B_1 = \frac{\mu_0 v}{4r_1}$$

$$B_2 = \frac{\mu_0 I}{4r_2}$$

$$\therefore \overline{B_{net}} = \overline{B_1} + \overline{B_2} = \frac{\mu_0 I}{4}\left[\frac{1}{r_1} + \frac{1}{r_2}\right]$$

$$= \frac{4\pi\times10^{-7}\times10}{4}\times\left[\frac{1}{0.08} + \frac{1}{0.12}\right]$$

$\therefore \overline{B_{net}} = 6.54\times10^{-5}\,T$ Outwards

Therefore, by right-hand thumb rule, $B = 6.06 \times 10^{-5}$T outward.

(*b*) Force acting on a current carrying conductor placed in a magnetic field is,

$\vec{F} = I(l \times B) = BIl\sin\theta$

At the center, $\theta = 180°$, therefore, force, $F = 0$.

On the segment CD,

$$dF = dx \times B = 10 \times dx \times \frac{\mu_0 I}{2\pi x}$$

$$F = \frac{5\mu_0 I}{\pi}\int_{r_2}^{r_1}\frac{dx}{x}$$

$$= \frac{5\times4\pi\times10^{-7}\times10}{\pi}\log\left[\frac{0.12}{0.08}\right]$$

$= 2\times10^{-5}\log[1.5]$

$\vec{F} = 8.1\times10^{-6}\,N$

The direction of force is downwards.

67. Required Force,

(*a*) $\vec{F} = q(v_0\hat{i})\times\frac{\mu_0 I}{4R}(\hat{i} - \hat{j})$

$$= \frac{\mu_0 I v_0 q}{4R}\left(-\hat{k}\right)$$

(*b*) Force on semicircular loop KLM due to external field B_0 is same as the force experienced by straight current carrying conductor along KM

$$F = -I\left(2R\hat{k}\right)\times B\hat{j} = 2IRB_0\hat{i}$$

Similarly,

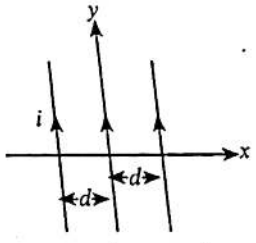
Force on the semicircular loop KMN

$= 2IRB_0\hat{i}$

Thus, net force on the loop, $\vec{F} = 4IB_0R\hat{i}$

68. Net magnetic field at some point x and y is zero.

(*a*)



$$B_{net} = \frac{\mu_0 I}{2\pi(x+d)} + \frac{\mu_0 I}{2\pi x} + \frac{\mu_0 I}{2\pi(x-d)} = 0$$

@FAKE_CBSE_KA@RAJ_ENGINET

$$\frac{1}{x+d}+\frac{1}{x}+\frac{1}{x-d}=0$$

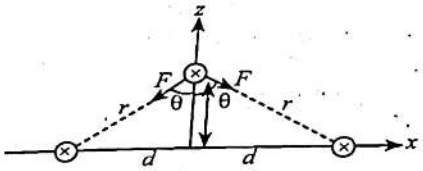
$$\frac{2x^2+x^2-d^2}{x\left(x^2-d^2\right)}=0 \Rightarrow 3x^2=d^2$$

$$x=\pm\sqrt{\frac{d}{3}}$$

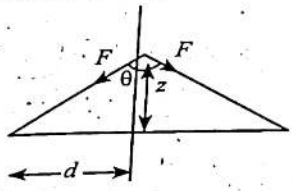
Net force will be zero only in $x-y$ plane i.e. when $z=0$ and

$$x=\pm\sqrt{\frac{d}{3}}$$

(b) Let the middle wire is displaced by z distance in positive x-direction.



Attractive force acting on wire is F



$$\cos\theta=\frac{z}{\sqrt{d^2+z^2}}$$

$$F=\frac{\mu_0 i^2}{2\pi\sqrt{d^2+z^2}}$$

The resultant force is downward

$$F_{net}=-2F\cos\theta=\frac{-2\mu_0 i^2}{2\pi\sqrt{d^2+z^2}}\cdot\frac{z}{\sqrt{d^2+z^2}}$$

$$F_{net}=\frac{-\mu_0 z i^2}{\pi(d^2+z^2)}$$

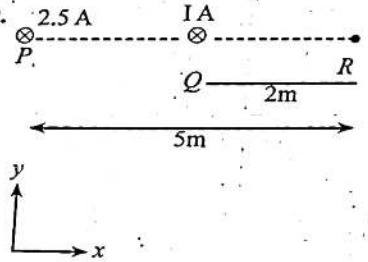
For small z

$$F_{net}=\frac{-\mu_0 i^2 z}{\pi d^2}=\lambda z\omega^2$$

$$\omega=\sqrt{\frac{\mu_0 i^2}{\lambda\pi d^2}}$$

$$f=\frac{\omega}{2\pi}=\frac{i}{2\pi d}\sqrt{\frac{\mu_0}{\lambda\pi}}$$

69.



$$\vec{B}_R=\vec{B}_P+\vec{B}_Q$$

$$=\left[\frac{\mu_0 i_P}{2\pi r_1}+\frac{\mu_0 i_Q}{2\pi r_2}\right](-\hat{j})$$

$$=\frac{\mu_0}{2\pi}\left[\frac{2.5}{5}+\frac{I}{2}\right](-\hat{j})$$

$$=\frac{4\pi\times10^{-7}}{2\pi}\left[\frac{I+1}{2}\right](-\hat{j})=10^{-7}(I+1)(-\hat{j})$$

(a) $F=qvB\sin 90°$

$3.2\times10^{-20}=1.6\times10^{-19}\times4\times10^{-5}\times10^{-7}(I+1)$

$\therefore\ I=4A$

(b) Net field at R due to wires P and Q is $B=10^{-7}(I+1)=5\times10^{-7}$ Wb/m²

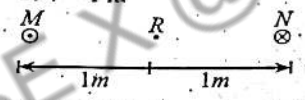
Magnetic field due to third wire carrying a current of 2.5 A should produce magnetic field equal to 5×10^{-7} wb/m² in upward direction so, that net field at R becomes zero, Let distance of this wire from R be r.

Then,

$$\frac{\mu_0}{2\pi}\frac{2.5}{r}=5\times10^{-7}\Rightarrow\frac{(2\times10^{-7})(2.5)}{r}$$

$$=5\times10^{-7}\text{ m}$$

$$\Rightarrow r=1\text{ m}$$



So, the third wire can be put at M or N as shown in figure. If it is placed at M, then current in it should be outwards and if placed at N, then current be inwards.

70. This force will act along z axis so, ILB is Z axis.

The expression of force is $F=I(1\times B)$

The angle between FE and B is 180°

BA and B is 0

For both of these $L\times B=0$

The angle between ED and B is 90°

Force on ED is $L\times B=ILB\sin 90°=ILB$

The angle between CB and B is 270°

Force on CB is $L\times B=ILB\sin 270°$

$=-ILB$

The force on ED or CB acts perpendicular to both ED and B or CB or Btowards x-axis.

These two factors cancel each other as they act opposite

The angle between DC and B is 90°

Force on DC is $L\times B=ILB\sin 90°$

$=ILB$

this force will act along z axis so, ILB is Z axis.

71. (a) $\phi=Li=\frac{\mu_0 m}{2\pi r^3}\times\pi a^2$

$$\Rightarrow I=\frac{\mu_0 m\pi a^2}{2\pi r^3 L}\Rightarrow I\propto\frac{m}{r^3}$$

72. (c) $\phi=Li=\frac{\mu_0 m}{2\pi r^3}\times\pi a^2$

$$\Rightarrow I=\frac{\mu_0 m\pi a^2}{2\pi r^3 L}\Rightarrow I\propto\frac{m}{r^3}$$

$$m'=\pi a^2 I=\frac{\mu_0 m\pi^2 a^4}{2\pi r^3 L}$$

$$F=\frac{km^2\pi^2 a^4}{2\pi r^7 L}$$

$$W=\int F dr\propto\int\frac{m^2 dr}{r^7}\Rightarrow W\propto\frac{m^2}{r^6}$$

73. (b) Torque experienced by circular loop $=\vec{M}\times\vec{B}$

$\tau=i\pi R^2 NB_0$ (at the instant shown)

Now, $d\vec{L}=\vec{\tau}dt=i\pi R^2 NB_0 dt$

$=Q\pi R^2 NB_0$ [$idt=Q$]

74. (c) $U=-MB=-MB\cos\theta$

Here, M= magnetic moment of the loop

q = angle between M and B

U is maximum when $\theta=180°$ and minimum when $\theta=0°$. So, as θ decreases from 180° to 0°, its PE also decreases.

75. (a) In non-uniform magnetic field, the needle will experience both a force and a torque.

76. In equilibrium, $2T_0=mg$

$$\Rightarrow T_0=\frac{mg}{2}$$

Magnetic moment, $\mu=IA=\frac{Q}{2\pi/\omega}\pi R^2$

$$=\frac{Q\omega R^2}{2}$$

Now, torque on the rod, $\tau=\mu B\sin 90°$

$$=\frac{Q\omega BR^2}{2}$$

Let T_1 and T_2 be the tensions in the two strings when the magnetic field is switched on, then

$T_1+T_2=mg$

For rotational equilibrium, torque acting should be balanced,

$$(T_1-T_2)\frac{D}{2}=\tau=\frac{Q\omega BR^2}{2}$$

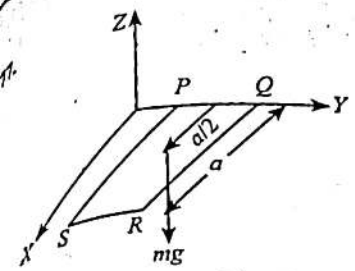
So,

$$(T_1-T_2)=T_0=\frac{Q\omega BR^2}{D}$$

Maximum angular speed with which the ring can be rotated is given by

$$\omega_{max}=\frac{DT_0}{BQR^2}=\frac{(1)(2)}{(0.05)(2)(0.5)^2}=80\text{ rad/s}$$

@TARGET_CBSE_X @RAJ_EDUNET



(a) Torque due to weight of coil,

$$\vec{\tau}=\left(\frac{a}{2}\hat{i}\right)\times\left(-mg\hat{k}\right)=mg\frac{a}{2}\hat{j}$$

For the equilibrium of the loop, torque on it must be along the negative y-axis.

Let the magnetic moment of loop be $\mu\hat{k}$. As the loop lies in the x–y plane, its magnetic moment vector (from right hand thumb rule) either points up or down.

Torque due to magnetic force,

$$\vec{\tau}_B=\mu\times\vec{B}=\mu\hat{k}\times\left(3\hat{i}+4\hat{k}\right)B_0=3\mu B_0\hat{j}$$

If it is in a negative direction, μ must point downward. So, the current in the coil must be from P to Q.

(b) Force acting on arm RS $=I(\vec{l}\times\vec{B})$

$$=I[(-b\hat{j})\times(3\hat{i}+4\hat{k})B_0]$$

$$=IB_0b(3\hat{k}-4\hat{i})$$

(c) In equilibrium, $\vec{\tau}_{grav}+\vec{\tau}_B=0$

Hence, $3(abI)B_0=\dfrac{mga}{2}$

Or, $I=\dfrac{mg}{6B_0b}$

78. (a) $\tau=MB=ki\Rightarrow k=\dfrac{MB}{i}=\dfrac{(NiA)B}{i}$

$$=NBA$$

(b) $\tau=k\cdot\theta=BiNA$

$$\therefore\ k=\frac{2BiNA}{\pi}\qquad(\text{as }\theta=\pi/2)$$

(c) $\tau=BiNA$

or $\int_0^t\tau dt=BNA\int_0^t idt\Rightarrow I\omega=BNAQ$

or $\omega=\dfrac{BNAQ}{I}$

At maximum deflection, whole kinetic energy (rotational) will be converted into potential energy of spring.

Hence, $\frac{1}{2}I\omega^2=\frac{1}{2}k\theta_{max}^2$

Substituting the values, we get

$$\theta_{max}=Q\sqrt{\frac{BN\pi A}{2I}}$$

79. (a) In ground state ($n=1$) according to Bohr's theory

$$mvR=\frac{h}{2\pi}\text{ or }v=\frac{h}{2\pi mR}$$

Now, time period,

$$T=\frac{2\pi R}{v}=\frac{2\pi R}{h/2\pi mR}=\frac{4\pi^2mR^2}{h}$$

Magnetic moment, $M=iA$

where, $i=\dfrac{\text{charge}}{\text{time period}}=\dfrac{e}{\frac{4\pi^2mR^2}{h}}$

$$=\frac{eh}{4\pi^2mR^2}\text{ and }A=\pi R^2$$

$$\therefore M=\left(\pi^2R^2\right)=\left(\frac{eh}{4\pi^2mR^2}\right)\text{ or }M=\frac{eh}{4\pi m}$$

Direction of magnetic moment M is perpendicular to the plane of orbit.

Alternate method

$$\frac{M}{L}=\frac{q}{2m}=\frac{e}{2m}$$

$$\therefore M=L\left(\frac{e}{2m}\right)=\left(\frac{h}{2\pi}\right)\left(\frac{e}{2m}\right)=\frac{eh}{4\pi m}$$

(b) $\tau=M\times B\Rightarrow|\tau|=MB\ \text{Sin}\theta$

where, θ is the angle between M and B

$\theta=30°$

$$\therefore\tau=\left(\frac{eh}{4\pi m}\right)(B)\sin30°\Rightarrow\tau=\left(\frac{ehB}{8\pi m}\right)$$

The direction of τ is perpendicular to both A and B.

80. Magnetic moment of the loop,

$$M=(iA)\hat{k}=\left(I_0L^2\right)\hat{k}$$

Magnetic field,

$$B=\left(B\cos45°\right)\hat{i}+\left(B\sin45°\right)\hat{j}$$

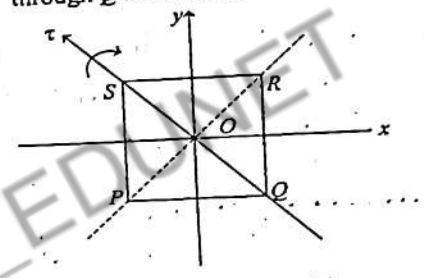
$$=\frac{B}{\sqrt{2}}(\hat{i}+\hat{j})$$

(a) Torque acting on the loop, $\tau=M\times B$

$$=\left(I_0L^2\hat{k}\right)\times\left[\frac{B}{\sqrt{2}}(\hat{i}+\hat{j})\right]$$

$$\therefore\ \tau=\frac{I_0L^2B}{\sqrt{2}}(\hat{j}-\hat{i})\text{ or }|\tau|=I_0L^2B$$

(b) Axis of rotation coincides with the torque passing through centre of mass, if net force on a body is zero. Here torque is along $(\hat{j}-\hat{i})$. Therefore, the loop will rotate about an axis passing through Q and S as shown in the figure.



Angular acceleration, $\alpha=\dfrac{|\tau|}{I}$

where, I = moment of inertia of loop about QS.

$I_{QS}+I_{FR}=I_{ZZ}$

(From theorem of perpendicular axis)

But

$I_{QS}+I_{FR}$

$$\therefore 2I_{QS}=I_{ZZ}=\frac{4}{3}ML^2$$

$$I_{QS}=\frac{2}{3}ML^2$$

$$\therefore\alpha=\frac{|\tau|}{I}=\frac{I_0L^2B}{\frac{2}{3}ML^2}=\frac{3}{2}\frac{I_0B}{M}$$

$\therefore$ Angle by which the frame rotates in time Δt is

$$\Delta\theta=\frac{1}{2}\alpha(\Delta t)^2\text{ or }\Delta\theta=\frac{3}{4}\frac{I_0B}{M}\cdot(\Delta t)^2$$

@FAKE_CBSE_X @RAJ_EDUNET

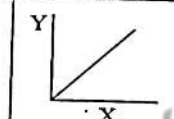
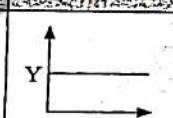
21 Magnetism and Matter

Scan for Sol.

JEE-Main

Magnetic Moment, Magnetisation, Magnetic Intersity and Magnetic Properties of Material

1. Match List-I with List-II

	List-I (Y vs X)		List-II (Shape of Graph)
(A)	Y = magnetic susceptibility X = magnetising field	(I)	
(B)	Y = magnetic field X = distance from centre of a current carrying wire for x < a (where a = radius of wire)	(II)	
(C)	Y = magnetic field X = distance from centre of a current carrying wire for x > a (where a = radius of wire)	(III)	
(D)	Y = magnetic field inside solenoid X = distance from center	(IV)	

Choose the correct answer from the options given below:
[06 April, 2024 (Shift-II)]

(a) (A)-(III), (B)-(I), (C)-(IV), (D)-(II)
(b) (A)-(I), (B)-(III), (C)-(II), (D)-(IV)
(c) (A)-(IV), (B)-(I), (C)-(III), (D)-(II)
(d) (A)-(III), (B)-(IV), (C)-(I), (D)-(II)

2. Paramagnetic substances:
A. align themselves along the directions of external magnetic field.
B. attract strongly towards external magnetic field.
C. has susceptibility little more than zero.
D. move from a region of strong magnetic field to weak magnetic field.

Choose the most appropriate answer from the options given below:
[08 April, 2024 (Shift-I)]

(a) A, B, C, D (b) B, D Only
(c) A, B, C Only (d) A, C Only

3. The coercivity of a magnet is 5×10^3 A/m. The amount of current required to be passed in a solenoid of length 30 cm and the number of turns 150, so that the magnet gets demagnetised when inside the solenoid is .....A. **[08 April, 2024 (Shift-II)]**

4. A straight magnetic strip has a magnetic moment of 44 Am^2. If the strip is bent in a semicircular shape, its magnetic moment will be ..... Am^2. **[09 April, 2024 (Shift-II)]**
(Given $\pi = 22/7$)

5. Given below are two statements:
Statement-I: For diamagnetic substance $-1 \leq \chi < 0$, where χ is the magneticsusceptibility.
Statement-II: Diamagnetic substances when placed in an external magnetic field, tend to move from stronger to weaker part of the field.
In the light of the above statements, choose the correct answer from the options given below. **[10 April, 2023 (Shift-II)]**

(a) Both Statement-I and Statement-II are false.
(b) Both Statement-I and Statement-II are true.
(c) Statement-I is incorrect but Statement-II is true.
(d) Statement-I is correct but Statement-II is false.

6. The magnetic moments associated with two closely wound circular coils A and B of radius $r_A = 10$ cm and $r_B = 20$ cm respectively are equal if: (Where N_A, I_B and N_B, I_A are number of turn and current of A and B respectively) **[30 Jan, 2023 (Shift-I)]**

(a) $2N_AI_A = N_BI_B$ (b) $N_A = 2N_B$
(c) $N_AI_A = 4N_BI_B$ (d) $4N_AI_A = N_BI_B$

7. Given below are two statements:
Statement-I: The diamagnetic property depends on temperature.
Statement-II: The induced magnetic dipole moment in a diamagnetic sample is always opposite to the magnetizing field.
In the light of given statement, choose the correct answer from the options given below: **[12 April, 2023 (Shift-I)]**

(a) Statement-I is incorrect but Statement-II is true
(b) Both Statement-I and Statement-II are true.
(c) Both Statement-I and Statement-II are false.
(d) Statement-I is correct but Statement-II is false.

AKE-ONLY@JEE-DOUBT

8. The current required to be passed through a solenoid of 15 cm length and 60 turns in order to demagnetise a bar magnet of magnetic intensity $2.4 \times 10^3\ Am^{-1}$ is ____ A. **[10 April, 2023 (Shift-I)]**

9. Given below are two statements: **[25 June, 2022 (Shift-II)]**

Statement-I: Susceptibilities of paramagnetic and ferromagnetic substances increase with decrease in temperature.

Statement-II: Diamagnetism is a result of orbital motions of electrons developing magnetic moments opposite to the applied magnetic field.

Choose the CORRECT answer from the options given below:-

(*a*) Both Statement-I and Statement-II are true.
(*b*) Both Statement-I and Statement-II are false.
(*c*) Statement-I is true but statement-II is false.
(*d*) Statement-I is false but Statement-II is true.

10. A bar magnet having a magnetic moment of $2.0 \times 10^5\ JT^{-1}$, is placed along the direction of uniform magnetic field of magnitude $B = 14 \times 10^{-5}\ T$. The work done in rotating the magnet slowly through 60° from the direction of field is: **[26 June, 2022 (Shift-II)]**

(*a*) 14 J (*b*) 11..4 J (*c*) 4 J (*d*) 1.4 J

11. Given below two statements: One is labelled as Assertion (A) and other is labelled as Reason (R). **[26 June, 2022 (Shift-I)]**

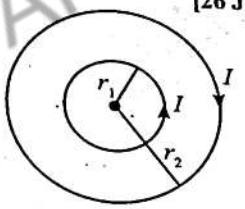
Assertion (A): Non-polar materials do not have any permanent dipole moment.

Reason (R): When a non-polar material is placed in an electric field, the centre of the positive charge distribution of it's individual atom or molecule coincides with the centre of the negative charge distribution.

In the light of above statements, choose the most appropriate answer from the options given below:

(*a*) Both (A) and (R) are correct and (R) is the correct explanation of (A).
(*b*) Both (A) and (R) are correct and (R) is not the correct explanation of (A).
(*c*) (A) is correct but (R) is not correct.
(*d*) (A) is not correct but (R) is correct.

12. Two concentric circular loops of radii $r_1 = 30\text{cm}$ and $r_2 = 50\text{cm}$ are placed in $X - Y$ plane as shown in the figure. A current $I = 7A$ is flowing through them in the direction as shown in figure. The net magnetic moment of this system of two circular loops is approximately: **[26 July, 2022 (Shift-II)]**



(*a*) $\frac{7}{2}\hat{k}\,\text{Am}^2$ (*b*) $-\frac{7}{2}\hat{k}\,\text{Am}^2$ (*c*) $7\hat{k}\,\text{Am}^2$ (*d*) $-7\hat{k}\,\text{Am}^2$

13. A wire of length 314 cm carrying current of 14 A is bent to form a circle. The magnetic moment of the coil is _____ Am^2. [Given $\pi = 3.14$] **[29 July, 2022 (Shift-I)]**

14. Which of the following statements are correct? **[18 March, 2021 (Shift-II)]**

(A) Electric monopoles do not exist whereas magnetic monopoles exist.
(B) Magnetic field lines due to a solenoid at its ends and outside cannot be completely straight and confined.
(C) Magnetic field lines are completely confined within a toroid.
(D) Magnetic field lines inside a bar magnet are not parallel.
(E) $\chi = -1$ is the condition for a perfect diamagnetic material, where χ is its magnetic susceptibility.

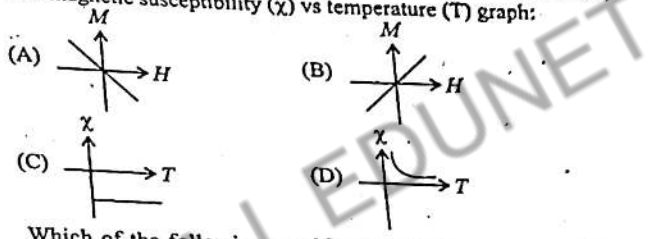
Choose the correct answer from the options given below:

(*a*) (A) and (B) only (*b*) (B) and (C) only
(*c*) (C) and (E) only (*d*) (B) and (D) only

15. A soft ferromagnetic material is placed in an external magnetic field. The magnetic domains: **[24 Feb, 2021 (Shift-II)]**

(*a*) Decrease in size and change orientation.
(*b*) Increases in size but no change in orientation.
(*c*) May increase or decrease in size and change its orientation.
(*d*) Have no relation with external magnetic field.

16. Following plots show magnetization (M) vs magnetising field (H) and magnetic susceptibility (χ) vs temperature (T) graph:



Which of the following combination will be represented by a diamagnetic material? **[1 Sept, 2021 (Shift-II)]**

(*a*) (B), (C) (*b*) (B), (D)
(*c*) (A), (C) (*d*) (A), (D)

17. **Statement-I:** The ferromagnetic property depends on temperature. At high temperature, ferromagnet becomes paramagnet. **[22 July, 2021 (Shift-II)]**

Statement-II: At high temperature, the domain wall area of a ferromagnetic substance increases.

In the light of the above statements, choose the most appropriate answer from the options given below:

(*a*) Both Statement-I and Statement-II are false
(*b*) Statement-I is true but Statement-II is false
(*c*) Statement-I is false but Statement-II is true
(*d*) Both Statement-I and Statement-II are true

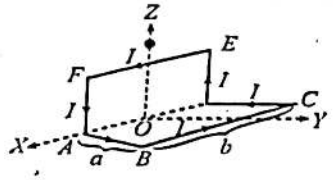
18. In a ferromagnetic material, below the curie temperature, a domain is defined as: **[25 Feb, 2021 (Shift-II)]**

(*a*) a macroscopic region with zero magnetization.
(*b*) a macroscopic region with saturation magnetization.
(*c*) a macroscopic region with randomly oriented magnetic dipoles.
(*d*) a macroscopic region with consecutive magnetic dipoles oriented in opposite direction.

19. A long solenoid with 1000 turns/m has a core material with relative permeability 500 and volume $10^3\ \text{cm}^3$. If the core material is replaced by another material having relative permeability of 750 with same volume maintaining same current of 0.75 A in the solenoid, the fractional change in the magnetic moment of the core would be approximately $\left(\frac{x}{499}\right)$. Find the value of x. **[31 Aug, 2021 (Shift-II)]**

@FAKE_CBSE_X_@RAJ_EDUNET

20. A wire carrying current I is bent in the shape $ABCDEFA$ as shown, where rectangle $ABCDA$ and $ADEFA$ are perpendicular to each other. If the sides of the rectangles are of lengths a and b, then the magnitude and direction of magnetic moment of the loop $ABCDEFA$ is **[2 Sep, 2020 (Shift-II)]**



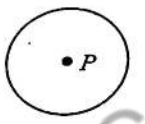
(a) abI, along $\left(\frac{\hat{j}}{\sqrt{5}}+\frac{2\hat{k}}{\sqrt{5}}\right)$ (b) $\sqrt{2}\,abI$, along $\left(\frac{\hat{j}}{\sqrt{2}}+\frac{\hat{k}}{\sqrt{2}}\right)$

(c) abI, along $\left(\frac{\hat{j}}{\sqrt{2}}+\frac{\hat{k}}{\sqrt{2}}\right)$ (d) $\sqrt{2}\,abI$, along $\left(\frac{\hat{j}}{\sqrt{5}}+\frac{2\hat{k}}{\sqrt{5}}\right)$

21. A charged particle going around in a circle can be considered to be a current loop. A particle of mass m carrying charge q is moving in a plane with speed v under the influence of magnetic field $\vec{B}$. The magnetic moment of this moving particle is **[6 Sep, 2020 (Shift-II)]**

(a) $\frac{mv^2\vec{B}}{2B^2}$ (b) $\frac{mv^2\vec{B}}{2B^2}$ (c) $-\frac{mv^2\vec{B}}{2\pi B^2}$ (d) $-\frac{mv^2\vec{B}}{B^2}$

22. A perfectly diamagnetic sphere has a small spherical cavity at its centre which is filled with a paramagnetic substance. The whole system is placed in a uniform magnetic field $\vec{B}$. Then the field inside the paramagnetic substance is **[3 Sep, 2020 (Shift-II)]**



(a) Much larger than $|\vec{B}|$ and parallel to $\vec{B}$

(b) $\vec{B}$

(c) Much larger than $|\vec{B}|$ and opposite to $\vec{B}$

(d) Zero

23. A paramagnetic sample shows a net magnetisation of 6 A/m when it is placed in an external magnetic field of 0.4 T at a temperature of 4 K. When the sample is placed in an external magnetic field of 0.3 T at a temperature of 24 K, then the magnetisation will be **[4 Sep, 2020 (Shift-II)]**

(a) 1 A/m (b) 0.75 A/m

(c) 4 A/m (d) 2.25 A/m

24. Consider a circular coil of wire carrying constant current I, forming a magnetic dipole. **[7 Jan, 2020 (Shift-I)]**

The magnetic flux through an infinite plane that contains the circular coil and excluding the circular coil area is given by ϕ. The magnetic flux through the area is given by ϕ_0.

Which of the following is correct?

(a) $\phi_i = -\phi_0$ (b) $\phi_i > \phi_0$

(c) $\phi_i = \phi_0$ (d) $\phi_i < \phi_0$

Bar Magnet

25. The magnetic potential due to a magnetic dipole at a point on its axis situated at a distance of 20 cm from its center is 1.5×10^{-5} Tm. The magnetic moment of the dipole is _____ Am^2. (Given: $\frac{\mu_0}{4\pi} = 10^{-7} TmA^{-1}$) **[29 Jan, 2024 (Shift-I)]**

26. The magnetic moment of a bar magnet is 0.5 Am^2. It is suspended in a uniform magnetic field of 8×10^{-2} T. The work done in rotating it from its most stable to most unstable position is: **[04 April, 2024 (Shift-II)]**

(a) 16×10^{-2} J (b) 8×10^{-2} J (c) 4×10^{-2} J (d) Zero

27. A bar magnet having a magnetic moment 5.0 Am^2 is placed in parallel position relative to a magnetic field of 0.4 T. The amount of work done in turning the magnet form parallel to antiparallel position relative to the field direction is **[31 Jan, 2023 (Shift-I)]**

(a) 4 J (b) 1 J (c) 2 J (d) Zero

28. Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R.

Assertion A: A bar magnet dropped through a metallic cylindrical pipe takes more time to come down compared to a non-magnetic bar with same geometry and mass.

Reason R: For the magnetic bar, Eddy currents are produced in the metallic pipe which oppose the motion of the magnetic bar.

In the light of the above statements, choose the correct answer from the options given below **[11 April, 2023 (Shift-II)]**

(a) Both A and R are true but R is not the correct explanation of A

(b) A is true but R is false

(c) Both A and R are true and R is the correct explanation of A

(d) A is false but R is true

29. A bar magnet is released from rest along the axis of a very long vertical copper tube. After some time the magnet will **[10 April, 2023 (Shift-II)]**

(a) Move down with almost constant speed

(b) Oscillate inside the tube

(c) Move down with an acceleration greater than g

(d) Move down with an acceleration equal to g

30. Two bar magnets oscillate in a horizontal plane in earth's magnetic field with time periods of 3s and 4s respectively. If their moments of inertia are in the ratio of 3 : 2, then the ratio of their magnetic moments will be: **[27 July, 2022 (Shift-I)]**

(a) 2 : 1 (b) 8 : 3 (c) 1 : 3 (d) 27 : 16

31. A bar magnet of length 14 cm is placed in the magnetic meridian with its north pole pointing towards the geographic north pole. A neutral point is obtained at a distance of 18 cm from the center of the magnet. If B_H = 0.4 G, the magnetic moment of the magnet is (1G = 10^{-4} T) **[16 March, 2021 (Shift-I)]**

(a) 2.880×10^3 J T^{-1} (b) 2.880 J T^{-1}

(c) 2.880×10^2 J T^{-1} (d) 28.80 J T^{-1}

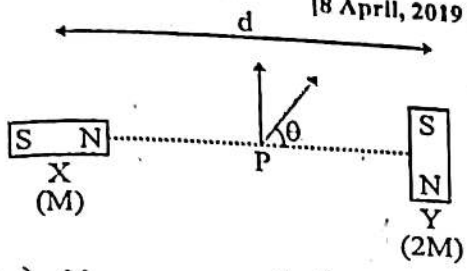
32. A small bar magnet placed with its axis at 30° with an external field of 0.06 T experiences a torque of 0.018 Nm. The minimum work required to rotate it from its stable to unstable equilibrium position is **[4 Sep, 2020 (Shift-I)]**

(a) 9.2×10^{-3} J (b) 6.4×10^{-2} J

(c) 7.2×10^{-2} J (d) 11.7×10^{-3} J

@FAKE_CBSE_X@RAMEEJNET

33. Two magnetic dipoles X and Y are placed at a separation d, with their axes perpendicular to each other. The dipole moment of Y is twice that of X. A particle of charge q is passing through their mid-point P, at angle $\theta = 45°$ with the horizontal line as shown in the figure. What would be the magnitude of force on the particle at that instant? (d is much larger than the dimensions of the dipole)
[8 April, 2019 (Shift-II)]



(a) $\sqrt{2}\left(\frac{\mu_0}{4\pi}\right)\frac{M}{(d/2)^3}\times qv$ (b) $\left(\frac{\mu_0}{4\pi}\right)\frac{2M}{(d/2)^3}\times qv$

(c) $\left(\frac{\mu_0}{4\pi}\right)\frac{M}{(d/2)^3}\times qv$ (d) 0

Vibration Magnetometer

34. For a moving coil galvanometer, the deflection in the coil is 0.05 rad when a current of 10mA is passed through it. If the torsional constant of the suspension wire is 4.0×10^{-5}, the magnetic field is 0.01 T and the number of turns in the coil is 200, the area of each turn (in cm^2) is:
[25 Jan, 2023 (Shift-II)]
(a) 2.0 (b) 1.0 (c) 1.5 (d) 0.5

35. The number of turns of the coil of a moving coil galvanometer is increased in order to increase current sensitivity by 50%. The percentage change in voltage sensitivity of the galvanometer will be:
[31 Jan, 2023 (Shift-II)]
(a) 100% (b) 50% (c) 75% (d) 0%

36. A compass needle of oscillation magnetometer oscillates 20 times per minute at a place P of dip 30°. The number of oscillations per minute become 10 at another place Q of 60° dip. The ratio of the total magnetic field at the two places ($B_Q : B_P$) is:
[27 July, 2022 (Shift-II)]
(a) $\sqrt{3}:4$ (b) $4:\sqrt{3}$ (c) $\sqrt{3}:2$ (d) $2:\sqrt{3}$

37. A hoop and a solid cylinder of same mass and radius are made of a permanent magnetic material with their magnetic moment parallel to their respective axes. But the magnetic moment of hoop is twice of solid cylinder. They are placed in a uniform magnetic field in such a manner that their magnetic moments make a small angle with the field. If the oscillation periods of hoop and cylinder are T_h and T_c respectively, then:
[10 Jan, 2019 (Shift-II)]
(a) $T_h = T_c$ (b) $T_h = 2T_c$ (c) $T_h = 1.5T_c$ (d) $T_h = 0.5_c$

38. At some location on earth the horizontal component of earth's magnetic field is 18×10^{-6} T. At this location, magnetic needle of length 0.12 m and pole strength 1.8 Am is suspended from its mid-point using a thread, it makes 45° angle with horizontal in equilibrium. To keep this needle horizontal, the vertical force that should be applied at one of its ends is :
[10 Jan, 2019 (Shift-II)]
(a) 3.6×10^{-5} N (b) 1.8×10^{-5} N
(c) 1.3×10^{-5} N (d) 6.5×10^{-5} N

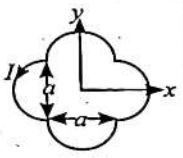
39. A magnetic compass needle oscillates 30 times per minute at a place where the dip is 45°, and 40 times per minute where the dip is 30°. If B_1 and B_2 are respectively the total magnetic field due to the earth at the two places, then the ratio B_1 / B_2 is best given by :
[12 April, 2019 (Shift-I)]
(a) 3.6 (b) 1.8 (c) 2.2 (d) 0.7

JEE-Advanced

Magnetisation, Magnetic Intensity and Magnetic Properties of Material

Single Correct

1. A loop carrying current I lies in the x-y plane as shown in the figure. The unit vector $\hat{k}$ is coming out of the plane of the paper. The magnetic moment of the current loop is
C-27.53 W-32.89 UA-39.58 (IIT-JEE 2012)



(a) $a^2 I\hat{k}$ (b) $\left(\frac{\pi}{2}+1\right)a^2 I\hat{k}$
(c) $-\left(\frac{\pi}{2}+1\right)a^2 I\hat{k}$ (d) $(2\pi+1)a^2 I\hat{k}$

2. A particle of charge q and mass m moves in a circular orbit of radius r with angular speed ω. The ratio of the magnitude of its magnetic moment to that of its angular momentum depends on **(IIT-JEE 2000)**
(a) ω and q (b) ω, q and m
(c) q and m (d) ω and m

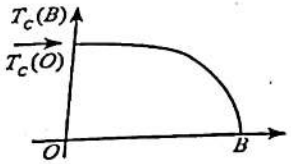
3. Two particles, each of mass m and charge q, are attached to the two ends of a light rigid rod of length $2R$. The rod is rotated at constant angular speed about a perpendicular axis passing through its centre. The ratio of the magnitudes of the magnetic moment of the system and its angular momentum about the centre of the rod is **(IIT-JEE 1998)**
(a) $q/2m$ (b) q/m
(c) $2q/m$ (d) $q/\pi m$

Comprehension Based/Statement Based

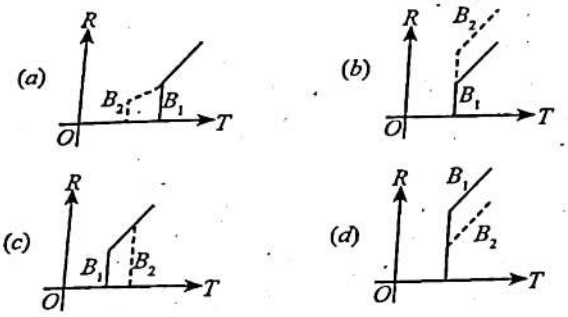
Directions (Q. 4-5): Electrical resistance of certain materials, known as superconductors, changes abruptly from a non-zero value to zero as their temperature is lowered below a critical temperature $T_c(0)$. An interesting property of superconductors is that their critical temperature becomes

@FAKE_CBSE_X @RAJ_EDUNET

smaller than $T_c(0)$ if they are placed in a magnetic field i.e. the critical temperature $T_c(B)$ is a function of the magnetic field strength B. The dependence of $T_c(B)$ on B is shown in the figure.



4. In the graphs below, the resistance R of a superconductor is shown as a function of its temperature T for two different magnetic fields B_1 (solid line) and B_2 (dashed line). If B_2 is larger than B_1, which of the following graphs shows the correct variation of R with T in these fields? **(IIT-JEE 2010)**



5. A superconductor has $T_c(0) = 100\ K$. When a magnetic field of 7.5 T is applied, its T_c decreases to 75 K. For this material one can definitely say that when (Note T = Tesla) **(IIT-JEE 2010)**

(a) $B = 5T,\ T_c(B) = 80\ K$

(b) $B = 5T,\ 75\ K < T_c(B) < 100\ K$

(c) $B = 10T,\ 75\ K < T_c(B) < 100\ K$

(d) $B = 10T,\ T_c(B) = 70\ K$

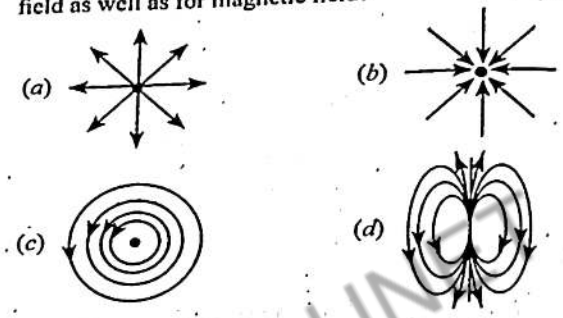
Fill in the Blanks

6. In a hydrogen atom, the electron moves in an orbit of radius 0.5 Å making 10^{16} revolutions per second. The magnetic moment associated with the orbital motion of the electron is ..... **(IIT-JEE 1988)**

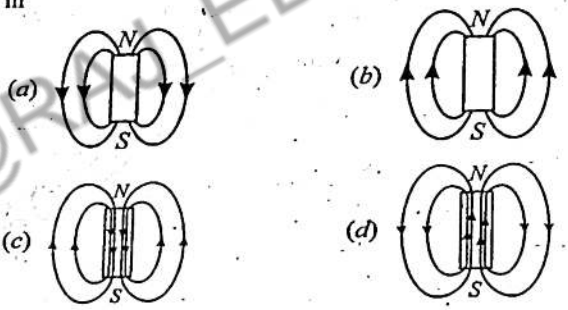
Bar Magnet

Single Correct

7. Which of the field patterns given in the figure is valid for electric field as well as for magnetic field? **(IIT-JEE 2011)**



8. The magnetic field lines due to a bar magnet are correctly shown in **(IIT-JEE 2002)**



@FAKE_CBSE X @RM_EDUNEET

ANSWER KEY

E-Main

. (a)	2. (d)	3. [10]	4. [28]	5. (b)	6. (c)	7. (a)	8. [6]	9. (a)	10. (a)
. (c)	12. (b)	13. [11]	14. (c)	15. (c)	16. (c)	17. (b)	18. (b)	19. [250]	20. (b)
(a)	22. (d)	23. (b)	24. (a)	25. [6]	26. (b)	27. (a)	28. (c)	29. (a)	30. (b)
(b)	32. (c)	33. (d)	34. (b)	35. (d)	36. (a)	37. (a)	38. (d)	39. (d)	

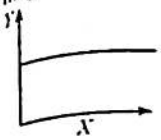
Advanced

(b)	2. (c)	3. (a)	4. (a)	5. (b)	6. (d)	7. (d)

EXPLANATIONS

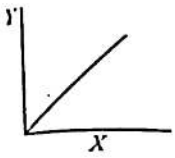
JEE-Main

1. (*a*) Magnetic susceptibility χ and magnetising field X:



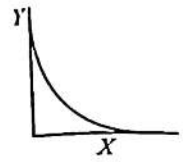
(B) For $x < a$:

$$B = \frac{\mu_0 ir}{2\pi a^2}$$

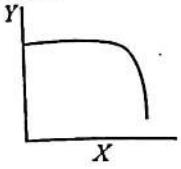


(C) For $x > a$:

$$B = \frac{\mu_0 i}{2\pi a}$$



(D) Variation of magnetic field inside solenoid:



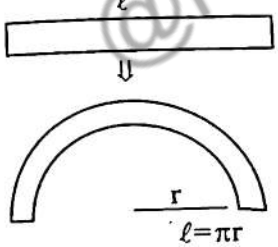
2. (*d*) A, C only

3. [10] The coercivity of the magnet,

$$H_c = \frac{\mu_0 ni}{\mu_0}$$

$$5\times10^3 = \frac{150}{30}\times100\times i \Rightarrow i = 10$$

4. [28] Magnetic moment of straight wire $= m \times \ell = 44$



Magnetic moment of arc = m × 2r

$$= m\times\frac{2\ell}{\pi} = \frac{44\times2}{\pi} = \frac{88}{\pi} = 28$$

5. (*b*) Both Statements are correct.

6. (c) $M = NIA$

$M_A = M_B$

$\therefore N_A I_A A_A = N_B I_B A_B$

$\therefore N_A I_A \pi(0.1)^2 = N_B I_B \pi(0.2)^2$

$\therefore N_A I_A = 4 N_B I_B$

7. (*a*) Diamagnetic property do not depend on the temperature.

8. [6] $H = ni = \frac{N}{\ell} i$, $i = \frac{H\ell}{N}$

$$i = \frac{2.4\times10^3\times15\times10^{-2}}{60} = 6A$$

9. (*a*) According to curie's law, magnetic susceptibility is inversely proportional to temperature for a fixed value of external magnetic field i.e. $\chi = \frac{C}{T}$.

The same is applicable for ferromagnet & the relation is given as $\chi = \frac{C}{T - T_C}$ (T_C is curie temperature)

Diamagnetism is due to non-cooperative behaviour of orbiting electrons when exposed to external magnetic field.

10. (*a*) Work done (W) = change in potential energy(ΔU).

$W = -MB\cos\theta_2 - (-MB\cos\theta_1)$

$= -MB[\cos\theta_2 - \cos\theta_1]$

$= -2\times10^5\times14\times10^{-5}(\cos60^\circ - \cos0^\circ)$

$= -28\left(\frac{1}{2} - 1\right) = 14J$

11. (*c*) In non-polar molecules, centre of positive charge coincides with centre of negative charge. Hence, net dipole moment becomes zero.

When non-polar material is placed in external field, centre of charge does not coincide. Hence, they give non-zero moment.

12. (*b*) Magnetic momentum, $\vec{M} = IA_1 - IA_2$

$= I\pi r_1^2\hat{k} - I\pi r_2^2\hat{k}$

$$\Rightarrow \vec{M} = 7\times\frac{22}{7}\times\left[\left(\frac{30}{100}\right)^2 d - \left(\frac{50}{100}\right)^2\right]\hat{k}\ \text{Am}^2$$

$$= 22\times\left(\frac{-16}{100}\right)\hat{k}\ \text{Am}^2$$

$$= -3.52\hat{k}\ \text{Am}^2 \approx -\frac{7}{2}\hat{k}\ \text{Am}^2$$

13. [11] $\ell = 2\pi r$

$\Rightarrow 314\text{cm} = 2\times3.14r$

$\Rightarrow r = 0.5\text{m}$

$\Rightarrow m = IA$

$= 14\times3.14\times\frac{1}{4} = 11$

14. (c) (*A*) Electric monopoles exist while magnetic monopoles do not exist.

(B) Magnetic field lines at the ends and outside of solenoid cannot be confined.

(C) Magnetic field lines are confined within a toroid.

(D) Magnetic field lines inside a bar magnet are parallel.

(E) For perfectly diamagnetic material.

15. (*c*) When a soft ferromagnetic substance is placed in external magnetic field, the size of domain lying in the direction of external magnetic field increases while size of domain lying in the opposite direction of field decreases if field is weak. However, if field is strong then the domain rotate in the direction of external magnetic field due to strong torque.

16. (*c*) The susceptibility of a diamagnetic material is a constant and it is negative.

17. (*b*) I: Ferromagnet becomes paramagnet at high temperature.

II: Domains area of ferromagnet tends to decrease break at high temperature.

18. (*b*) In ferromagnetic material , below Curie's temperature, a domain is defined as macroscopic region with zero magentisation.

19. [250] Fractional change in magnetic moment is

$$\frac{\Delta M}{M} = \frac{\Delta\mu}{\mu} = \frac{250}{500} = \frac{1}{2}$$

$$\Rightarrow \frac{x}{499} = \frac{1}{2}$$

$$\Rightarrow x = 250$$

20. (*b*) $\vec{M} = \vec{M}_1 + \vec{M}_2$

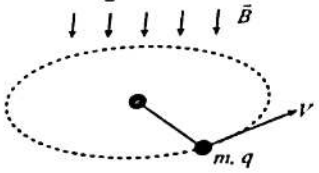
$\vec{M}_1 = abl\,\hat{j}$

$\vec{M}_2 = abl\,\hat{k}$

$$\vec{M} = \sqrt{2}\,abl\left(\frac{\hat{j}}{\sqrt{2}} + \frac{\hat{k}}{\sqrt{2}}\right)$$

@FAKE_CBSE_X @RAJ_EDUNET

21. (a) $\vec{M} = \frac{1}{2}qvR(-\hat{B})$



$= \frac{qv}{2}\left(\frac{mv}{qB}\right)\left(\frac{-\vec{B}}{B}\right)$

$= -\frac{mv^2}{2B^2}\vec{B}$

22. (d) Magnetic field inside perfectly diamagnetic material remains zero.

23. (b) $M \propto \frac{B}{T}$, $\Rightarrow \frac{M_2}{M_1} = \frac{B_2}{B_1} \times \frac{T_1}{T_2}$

$\Rightarrow \frac{x}{6} = \frac{0.3}{0.4} \times \frac{4}{24}$

$\Rightarrow x = 0.75$ A/m

24. (a) As magnetic field lines going inside is equal to the magnetic field lines coming out.

$\therefore \phi_i = -\phi_o$

25. [6] Given, $r = 20$ cm

$V = 1.5 \times 10^{-5}$ Tm

$V = \frac{\mu_0}{4\pi}\frac{M}{r^2}$

$\Rightarrow 1.5\times10^{-5} = 10^{-7} \times \frac{M}{\left(20\times10^{-2}\right)^2}$

$\Rightarrow M = \frac{1.5\times10^{-5}\times20\times20\times10^{-4}}{10^{-7}}$

$M = 1.5 \times 4 = 6$ Am^2

26. (b) Work done in rotating from stable to unstable position

$W = -mB\cos 180° - (-mB\cos 0°) = 2MB$

$= 2\times0.5\times8\times10^{-2} = 8\times10^{-2}$ J

27. (a) $W = -MB(\cos\theta 2 - \cos\theta 1)$

$W = 2MB = 2 \times 5 \times 0.4 = 4$ J

28. (c) Both A and R are true and R is the correct explanation of A.

29. (a) After some time, the magnet will move with constant speed because of two equal force on magnat.

30. (b) $T_1 = 3$sec, $T_2 = 4$sec, $\frac{I_1}{I_2} = \frac{3}{2}$

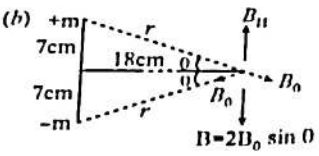
Formula,

$T = 2\pi\sqrt{\frac{I}{\mu B}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{I_1\mu_2}{\mu_1 I_2}}$

$\Rightarrow \frac{\mu_2}{\mu_1} = \frac{I_2}{I_1} \times \left(\frac{T_1}{T_2}\right)^2 = \frac{2}{3} \times \frac{9}{16} = \frac{3}{8}$

$\therefore \frac{\mu_1}{\mu_2} = \frac{8}{3}$

31. (b)



i.e. $\frac{2\mu_0}{4\pi}\frac{m}{r^2} \times \frac{7}{r} = 0.4\times10^{-4}$

$\Rightarrow 2\times10^{-7} \times \frac{m\times7}{(7^2+18^2)^{3/2}} \times 10^4$

$= 0.4 \times 10^{-4}$

$m = \frac{4\times10^{-2}\times(373)^{3/2}}{14}$

$M = m \times 14$ cm $= m \times \frac{14}{100}$

$= \frac{0.04\times(373)^{3/2}}{14} \times \frac{14}{100}$

$= 4 \times 10^{-4} \times 7203.82 = 2.88$ J/T

32. (c) $\tau = MB\sin\theta$

$0.018 = M \times 0.06 \times 0.5$

$\Rightarrow M = 0.6$ Am^2

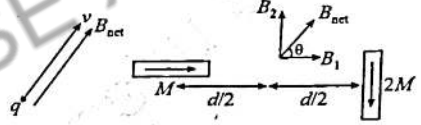
$W = U_f - U_i$

$= MB(\cos\theta_i - \cos\theta_f)$

$= 0.06 \times 0.06(1 - (-1)) = 7.2 \times 10^{-2}$ J

33. (d) **For dipole X:**

$B_X = 2\left(\frac{\mu_0}{4\pi}\right)\frac{M}{(d/2)^3}$

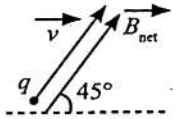


For dipole Y:

$B_2 = \left(\frac{\mu_0}{4\pi}\right)\frac{2M}{(d/2)^3}$

$\because B_1 = B_2$

$\therefore B_{net}$ is at 45° from the horizontal line.



Velocity of charge q at 45° from the horizontal line.

Force on charge, $F = q\left(\vec{v}\times\vec{B}\right) = 0$

34. (b) For the equilibrium of the coil of a moving coil galvonometer, $\tau = K\theta$

where k is torsional constant

$\Rightarrow NiAB = K\theta$

$\Rightarrow A = \frac{K\theta}{NiB} = \frac{4\times10^{-5}\times0.05}{200\times10\times10^{-1}\times0.01}$

$\Rightarrow A = 1$ cm^2

35. (d) Current sensitivity = voltage sensitivity × R

since current sensitivity is made 1.5 times Therefore, R also increases 1.5 time.

Hence, voltage sensitivity

$= \frac{1.5 \text{ current sensitivity}}{1.5R}$ = no change

36. (a) $T = 2\pi\sqrt{\frac{1}{B_H M}} = 2\pi\sqrt{\frac{I}{(B\cos\alpha).M}}$

therefore, for $\alpha = 30°$

$T_1 = 3s = 2\pi\sqrt{\frac{1}{\left(B_P\cos30°\right)M}}$

For, $\alpha = 60°$

$T_2 = 6s = 2\pi\sqrt{\frac{1}{\left(B_Q\cos60°\right)M}}$

$\frac{T_1}{T_2} = \frac{3}{6} = \sqrt{\frac{1}{\left(B_P\frac{\sqrt{3}}{2}\right)} \times \left(B_Q/2\right)}$

$\frac{1}{2} = \sqrt{\left(\frac{B_Q}{\sqrt{3}B_P}\right)}$

$\frac{B_Q}{B_P} = \frac{\sqrt{3}}{4}$

37. (a) $\because T = 2\pi\sqrt{\frac{1}{\mu B}}$

$\frac{T_h}{T_c} = \sqrt{\frac{I_h}{I_c} \times \frac{\mu_c}{\mu_h}} = \sqrt{\frac{2I_c}{I} \times \frac{\mu_c}{2\mu_c}} = 1$

$\therefore T_h = T_c$

38. (d) $\tau = mB_v\sin\theta = \frac{FI}{2}\sin\theta$

$F = \frac{2mB_v}{I} = 2\times1.8\times18\times10^{-6}$

$F = 6.5 \times 10^{-5}$ N

39. (d) Frequency of oscillation

$f = \frac{1}{2\pi}\sqrt{\frac{\mu B\cos\theta}{I}}$

$\therefore f \alpha \sqrt{B\cos\theta}$

$\therefore \frac{f_1}{f_2} = \sqrt{\frac{B_1\cos45°}{B_2\cos30°}}$

$\left(\frac{30}{40}\right)^2 = \frac{B_1}{B_2} \times \sqrt{\frac{2}{3}}$

$\therefore \frac{B_1}{B_2} = \frac{9}{16} \times \sqrt{\frac{3}{2}} = 0.7$

@PARE_CBSE_@RAJ_EDUNET

1. (*b*) Area of the given loop is

A = (area of two circles of radius $\frac{a}{2}$ and area of a square of side a)

$$= 2\pi\left(\frac{a}{2}\right)^2 + a^2 = \left(\frac{\pi}{2}+1\right)a^2$$

$$|M| = IA = \left(\frac{\pi}{2}+1\right)a^2 I$$

From screw law direction of M is outwards or in positive z-direction.

$$\therefore M = \left(\frac{\pi}{2}+1\right)a^2 I\hat{k}$$

2. (*c*) Ratio of magnetic moment and angular momentum is given by

$$\frac{M}{L} = \frac{q}{2m}$$

which is a function of q and m only. This can be derived as follows,

$$M = iA = (qf)\cdot(\pi r^2)$$

$$= (q)\left(\frac{\omega}{2\pi}\right)(\pi r^2) = \frac{q\omega r^2}{2}$$

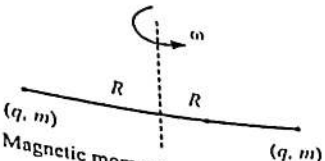
And $L = I\omega = (mr^2\omega)$

$$\therefore \frac{M}{L} = \frac{q\frac{\omega r^2}{2}}{mr^2\omega} = \frac{q}{2m}$$

3. (*a*) Current, i = (frequency) (charge)

$$= \left(\frac{\omega}{2\pi}\right)(2q) = \frac{q\omega}{\pi}$$

JEE-Advanced



Magnetic moment,

$$M = (i)(A) = \left(\frac{q\omega}{\pi}\right)(\pi R^2) = (q\omega R^2)$$

Angular momentum,

$$L = 2I\omega = 2(mR^2)\omega$$

$$\therefore \frac{M}{L} = \frac{q\omega R^2}{2(mR^2)\omega} = \frac{q}{2m}$$

4. (*a*) At $R = 0 \Rightarrow T_0(B_1) > T_0(B_2)$

Thus,

$B_2 > B_1 \Rightarrow T_0(B_1) > T_0(B_2)$

5. (*b*) We can observe from the graph that when B increases, $T_c(B)$ decreases and becomes a superconductor. But its exact dependence on the magnetic field cannot be determined from the graph. It is given that the superconductor has a critical temperature of 100 K when no magnetic field is applied, and it decreases to 75 K when the magnetic field is increased to 7.5 T. Since, we know that with increase in magnetic field, critical temperature decreases. When $B = 5\ T$, which lies between the magnetic field $0T$ and $7.5\ T$, critical temperature of the superconductor will lie between $T_c(0)$ and $T_c(100)$. That is, the critical temperature of a superconductor will lie between 75 K and 100 K when the magnitude of the magnetic field is $5T$.

6. Equivalent current $i = qf$

and magnetic moment $m = (i\pi^2) = \pi qfr^2$

Substituting the values, we have

$M = (\pi)\ (0.5 \times 10^{-10})^2\ (10^{16})\ (1.6 \times 10^{-19}$

$= 1.26 \times 10^{23} A - m^2$

7. (*d*) In the diagrams (*a*) and (*b*), the field lines are outward and inward due to a stationary point charge. These represent the electric field lines only because the magnetic field lines are only possible for a moving point charge which has some velocity.

In diagram (*c*), such magnetic field lines are possible for a current carrying wire coming out of the page. Circular electric field lines are not possible for any point charge or a current carrying wire.

For diagram (*d*), we see that such field lines are possible for a bar magnet's magnetic field and electric dipoles electric field.

8. (*d*) Magnetic lines form closed loop. Inside magnet, these are directed from South to North-pole.

@FAKE_CBSE X ORAJ_ENGINEER

22 Electromagnetic Induction

Scan for Sol.

JEE-Main

Magnetic Flux and Faraday's Laws of EMI, Lenz's Law

1. A rectangular loop of length 2.5 m and width 2 m is placed at 60° to a magnetic field of 4T. The loop is removed from the field in 10 sec. The average emf induced in the loop during this time is
[27 Jan, 2024 (Shift-I)]
(a) $-2V$ (b) $+2V$ (c) $+1V$ (d) $-1V$

2. A square loop of side 10 cm and resistance 0.7Ω is placed vertically in east-west plane. A uniform magnetic field of 0.20 T is set up across the plane in north east direction. The magnetic field is decreased to zero in 1s at a steady rate. Then, magnitude of induced emf is $\sqrt{x} \times 10^{-3}$V. The value of x is _____.
[29 Jan, 2024 (Shift-I)]

3. Match List-I with List-II.

List-I		List-II	
A.	Gauss's law of magnetostatics	I.	$\oint \vec{E}\cdot\vec{da}=\frac{1}{\varepsilon_0}\int \rho dV$
B.	Faraday's law of electro magnetic induction	II.	$\oint \vec{B}\cdot\vec{da}=0$
C.	Ampere's law	III.	$\oint \vec{E}\cdot\vec{dl}=\frac{-d}{dt}\int \vec{B}\cdot\vec{da}$
D.	Gauss's law of electrostatics	IV.	$\oint \vec{B}\cdot\vec{dl}=\mu_0 I$

Choose the correct answer from the options given below:
[30 Jan, 2024 (Shift-II)]
(a) A-I, B-III, C-IV, D-II (b) A-III, B-IV, C-I, D-II
(c) A-IV, B-II, C-III, D-I (d) A-II, B-III, C-IV, D-I

4. A coil is placed perpendicular to a magnetic field of 5000 T. When the field is changed to 3000 T in 2s, an induced emf of 22 V is produced in the coil. If the diameter of the coil is 0.02 m, then the number of turns in the coil is:
[31 Jan, 2024 (Shift-I)]
(a) 7 (b) 70 (c) 35 (d) 140

5. The magnetic flux ϕ (in weber) linked with a closed circuit of resistance 8 Ω varies with time (in seconds) as $\phi = 5t^2 - 36t + 1$. The induced current in the circuit at t = 2s is _____ A.
[31 Jan, 2024 (Shift-II)]

6. A coil is placed in magnetic field such that plane of coil is perpendicular to the direction of magnetic field. The magnetic flux through a coil can be changed:
[1 Feb, 2023 (Shift-II)]
A. By changing the magnitude of the magnetic field within the coil.
B. By changing the area of coil within the magnetic field.
C. By changing the angle between the direction of magnetic field and the plane of the coil.
D. By reversing the magnetic field direction abruptly without changing its magnitude.
Choose the most appropriate answer from the options given below:
(a) A and B only (b) A, B and C only
(c) A, B and D only (d) A and C only

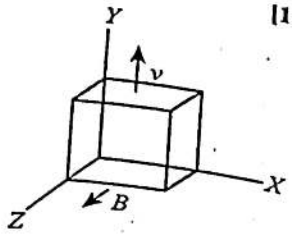
7. A conducting loop of radius $\frac{10}{\sqrt{\pi}} cm$ is placed perpendicular to a uniform magnetic field of 0.5 T. The magnetic field is decreased to zero in 0.5 s at a steady rate. The induced emf in the circular loop at 0.25 s is:
[24 Jan, 2023 (Shift-I)]
(a) $emf = 1\ mV$ (b) $emf = 10\ mV$
(c) $emf = 100\ mV$ (d) $emf = 5\ mV$

8. A square loop of area 25 cm² has a resistance of 10Ω. The square loop is placed in a uniform magnetic field of magnitude 40.0 T. The plane of the loop is perpendicular to the magnetic field. The work done in pulling the loop out of the magnetic field slowly and uniformly in 1.0 sec, will be
[29 Jan, 2023 (Shift-II)]
(a) 2.5×10^{-3} J (b) 1.0×10^{-3} J
(c) 1.0×10^{-4} J (d) 5×10^{-3} J

9. An insulated copper wire of 100 turns is wrapped around a wooden cylindrical core of the cross-sectional area 24 cm². The two ends of the wire are connected to a resistor. The total resistance in the circuit is 12Ω. If an externally applied uniform magnetic field in the core along its axis changes from 1.5 T in one direction to 1.5 T in the opposite direction, the charge flowing through a point in the circuit during the change of magnetic field will be _____ mC.
[13 April, 2023 (Shift-II)]

@TAKE_JRSE X@RAJ_BUNET

12. A metallic cube of side 15 cm moving along y-axis at a uniform velocity of 2 ms^{-1}. In a region of uniform magnetic field of magnitude 0.5 T directed along z-axis. In equilibrium the potential difference between the faces of higher and lower potential developed because of the motion through the field will be _____ mV.
[11 April, 2023 (Shift-II)]



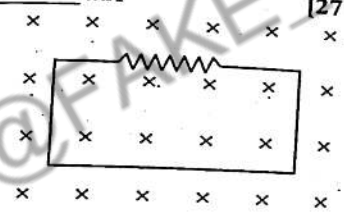
11. The magnetic flux through a coil perpendicular to its plane is varying according to the relation $\phi = (5t^3 + 4t^2 + 2t - 5)$ Weber. If the resistance of the coil is 5Ω, then the induced current through the coil at $t = 2s$ will be,
[26 June, 2022 (Shift-I)]
(a) 15.6 A (b) 16.6 A (c) 17.6 A (d) 18.6 A

12. A conducting circular loop is placed in $X-Y$ plane in presence of magnetic field $\vec{B} = (3t^3\hat{j} + 3t^2\hat{k})$ in SI unit. If the radius of the loop is 1 m, the induced emf in the loop, at time, $t = 2$ s is $n\pi V$. The value of n is _____.
[27 July, 2022 (Shift-II)]

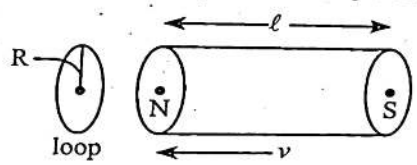
13. In a coil of resistance 8Ω, the magnetic flux due to an external magnetic field varies with time as $\phi = \frac{2}{3}(9 - t^2)$. The value of total heat produced in the coil, till the flux becomes zero, will be _____ J.
[26 July, 2022 (Shift-II)]

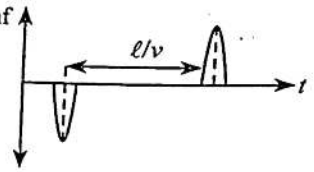
14. Magnetic flux (in weber) in a closed circuit of resistance 20Ω varies with time t(s) as $\phi = 8t^2 - 9t + 5$. The magnitude of the induced current at $t = 0.25$ s will be _____ mA.
[25 July, 2022 (Shift-II)]

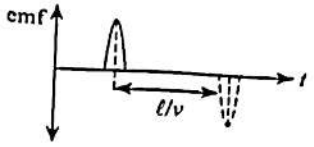
15. In the given figure the magnetic flux through the loop increases according to the relation $\phi_B(t) = 10t^2 + 20t$, where ϕ_B is milli-webers and t is in seconds. The magnitude of current through $R = 2\Omega$ resistor at $t = 5$ s is _____ mA
[27 July, 2021 (Shift-II)]

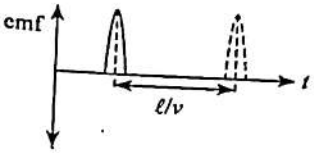


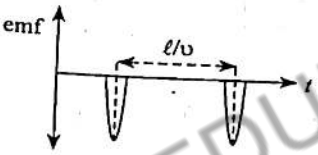
16. A bar magnet is passing through a conducting loop of radius R with velocity v. The radius of the bar magnet is such that it just passes through the loop. The induced e.m.f. in the loop can be represented by the approximate curve:
[27 Aug, 2021 (Shift-I)]



(a)


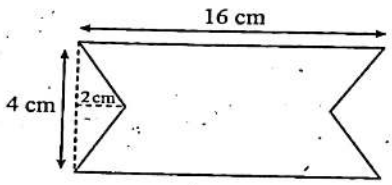
(b)


(c)


(d)


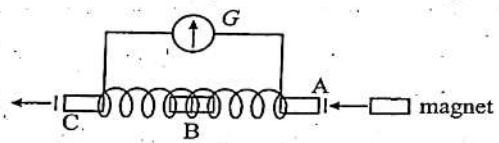
17. A long solenoid of radius R carries a time(t) dependent current $I(t) = I_0 t(1-t)$. A ring of radius $2R$ is placed cordially near its middle. During the time interval $0 \le t \le 1$, the induced current (I_R) and the induced emf(V_R) in the ring change as:
[7 Jan, 2020 (Shift-I)]
(a) Direction of I_R remains unchanged and V_R is zero at $t = 0.25$
(b) At $t = 0.5$ direction of I_R reverses and V_R is zero
(c) At $t = 0.25$ direction of I_R reverses and V_R is maximum
(d) Direction of I_R remains unchanged and V_R is maximum at $t = 0.5$

18. At time $t = 0$ magnetic field of 1000 gauss is passing perpendicularly through the area defined by the closed loop shown in the figure. If the magnetic field reduces linearly to 500 gauss, in the next 5 s, then induced emf in the loop is:
[8 Jan, 2020 (Shift-I)]



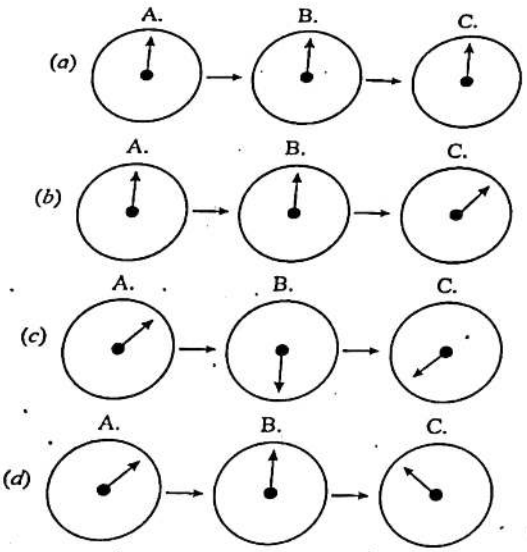
(a) 28 μV (b) 36 μV (c) 48 μV (d) 56 μV

19. A small bar magnet is moved through a coil at constant speed from one end to the other. Which of the following series of observations will be seen on the galvanometer G attached across the coil?
[4 Sep, 2020 (Shift-I)]



Three positions shown describe:
A. the magnet's entry
B. magnet is completely inside and
C. magnet's exit.

@FAKE_BOY @RAJEDUNET



20. Two concentric circular coils, C_1 and C_2 are placed in the XY plane. C_1 has 500 turns, and a radius of 1 cm. C_2 has 200 turns and radius of 20 cm. C_2 carries a time dependent current $I(t) = (5t^2 - 2t + 3)$ A where t is in seconds. The emf induced in C_1 (in mV), at the instant $t = 1$ s is $\frac{4}{x}$. The value of x is _____. **[5 Sep, 2020 (Shift-I)]**

Motional Emf

21. A horizontal straight wire 5 m long extending from east to west falling freely at right angle to horizontal component of earth's magnetic field 0.60×10^{-4} Wbm^{-2}. The instantaneous value of emf induced in the wire when its velocity is 10 ms^{-1} is _____ $\times 10^{-3}$ V.

[29 Jan, 2024 (Shift-II)]

22. A ceiling fan having 3 blades of length 80 cm each is rotating with an angular velocity of 1200 rpm. The magnetic field of earth in that region is 0.5 G and angle of dip is 30°. The emf induced across the blades is $N\pi \times 10^{-5}$ V. The value of N is _____.

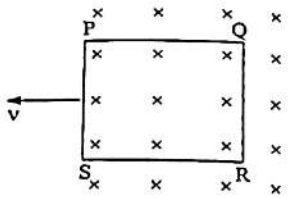
[30 Jan, 2024 (Shift-I)]

23. A rectangular loop of sides 12 cm and 5 cm, with its sides parallel to the x-axis and y-axis respectively moves with a velocity of 5 cm/s in the positive x axis direction, in a space containing a variable magnetic field in the positive z direction. The field has a gradient of 10^{-3}T/cm along the negative x direction and it is decreasing with time at the rate of 10^{-3} T/s. If the resistance of the loop is 6 mΩ, the power dissipated by the loop as heat is _____ $\times 10^{-9}$ W.

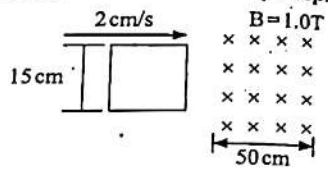
[1 Feb, 2024 (Shift-I)]

24. A square loop PQRS having 10 turns, area 3.6×10^{-3} m^2 and resistance 100 Ω is slowly and uniformly being pulled out of a uniform magnetic field of magnitude $B = 0.5$ T as shown. Work done in pulling the loop out of the field in 1.0s is _____ $\times 10^{-6}$ J.

[08 April, 2024 (Shift-I)]



25. A square loop of side 15 cm being moved towards right at a constant speed of 2 cm/s as shown in figure. The front edge enters the 50 cm wide magnetic field at t = 0. The value of induced emf in the loop at $t = 10s$ will be: **[09 April, 2024 (Shift-II)]**



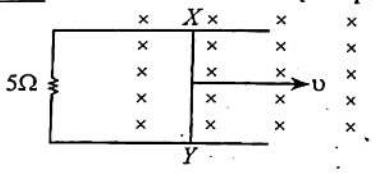
(a) 0.3 mV (b) 4.5 mV (c) zero (d) 3 mV

26. A wire of length 1m is moving with a velocity of 8m/s at right angles to a magnetic field of 2T. The magnitude of induced emf, between the ends of wire the will be **[25 Jan, 2023 (Shift-II)]**
(a) 20 V (b) 8 V (c) 12 V (d) 16 V

27. An emf of 0.08 V is induced in a metal rod of length 10 cm held normal to a uniform magnetic field of 0.4 T, when moves with a velocity of: **[8 April, 2023 (Shift-II)]**
(a) 2 ms^{-1} (b) 3.2 ms^{-1} (c) 0.5 ms^{-1} (d) 20 ms^{-1}

28. A square loop of side 2.0 cm is placed inside a long solenoid that has 50 turns per centimetre and carries a sinusoidally varying current of amplitude 2.5 A and angular frequency 700 rad s^{-1}. The central axes of the loop and solenoid coincide. The amplitude of the emf induced in the loop is $x \times 10^{-4}$ V. The value of x is _____.
(Take, $\pi = \frac{22}{7}$) **[10 April, 2023 (Shift-II)]**

29. A 1 m long metal rod XY completes the circuit as shown in figure. The plane of the circuit is perpendicular to the magnetic field of flux density 0.15 T. If the resistance of the circuit is 5Ω, the force needed to move the rod in direction, as indicated, with a constant speed of 4 m/s will be _____ $x \times 10^{-3}$ N **[10 April, 2023 (Shift-I)]**



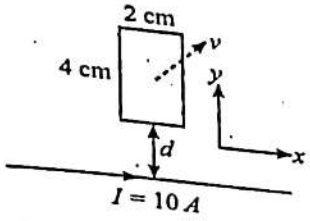
30. A single turn current loop in the shape of a right angle triangle with sides 5 cm, 12 cm, 13 cm is carrying a current of 2 A. The loop is in a uniform magnetic field of magnitude 0.75 T whose direction is parallel to the current in the 13 cm side of the loop. The magnitude of the magnetic force on the 5 cm side will be $\frac{x}{130}N$. The value of x is _____. **[24 Jan, 2023 (Shift-II)]**

31. In an ac generator, a rectangular coil of 100 turns each having area 14×10^{-2} m^2 is rotated at 360 rev/min about an axis perpendicular to a uniform magnetic field of magnitude 3.0 T. The maximum value of the emf produced will be _____ V. $\left(\text{Take } \pi = \frac{22}{7}\right)$

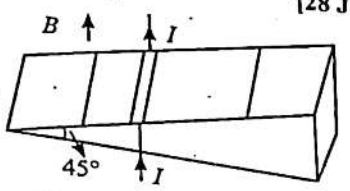
[30 Jan, 2023 (Shift-II)]

@FAST CBSE X @RAJ EDUNET

32. ...ucting loop of length 4 cm and width 2 cm is in the xy-plane, as shown in the figure. It is being moved away from a thin and long conducting wire along the direction $\frac{\sqrt{3}}{2}\hat{x}+\frac{1}{2}\hat{y}$ with a constant speed v. The wire is carrying a steady current $I = 10$ A in the positive x-direction. A current of 10 μA flows through the loop when it is at a distance $d = 4$ cm from the wire. If the resistance of the loop is 0.1 Ω, then the value of v is _____ ms^{-1}.
[Given: The permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ NA^{-2}]
[JEE Adv, 2023]



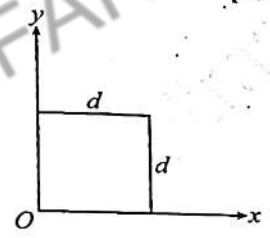
33. As shown in the figure, a metallic rod of linear density 0.45 kgm^{-1} is lying horizontally on a smooth incline plane which makes an angle of 45° with the horizontal. The minimum current flowing in the rod required to keep it stationary, when 0.15 T magnetic field is acting on it in the vertical upward direction, will be:
{Use g = 10 m/s^2}
[28 July, 2022 (Shift-I)]



(a) 30 A (b) 15 A (c) 10 A (d) 3 A

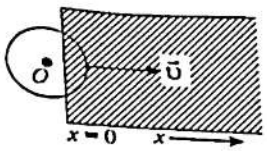
34. A metallic rod of length 20 cm is placed in North-South direction and is moved at a constant speed of 20 m/s towards East. The horizontal component of the Earth's magnetic field at that place is 4×10^{-3} T and the angle of dip is 45°. The emf induced in the rod is ____ mV.
[27 June, 2022 (Shift-II)]

35. The magnetic field in a region is given by $\vec{B} = B_0\left(\frac{x}{a}\right)\hat{k}$. A square loop of side d is placed with its edges along the x and y axes. The loop is moved with a constant velocity $\vec{v} = v_0\,\hat{i}$. The emf induced in the loop is:
[16 March, 2021 (Shift-II)]



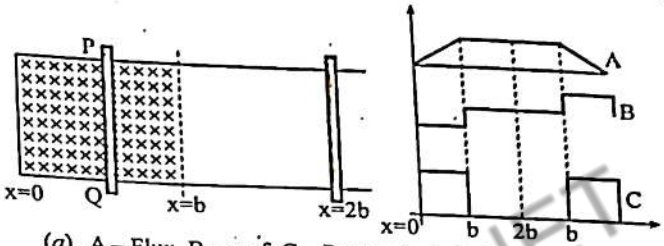
(a) $\frac{B_0 v_0 d^2}{a}$ (b) $\frac{B_0 v_0}{2a}$ (c) $\frac{B_0 v_0^2 d}{2a}$ (d) $\frac{B_0 v_0 d^2}{2a}$

36. A constant magnetic field of 1 T is applied in the $x > 0$ region. A metallic circular ring of radius 1m is moving with a constant velocity of 1 m/s along the x-axis. At $t = 0$, the centre of O of the ring is at $x = -1$m. What will be the value of the induced emf in the ring at $t = 1$ s? (Assume the velocity of the ring does not change.)
[27 Aug, 2021 (Shift-II)]



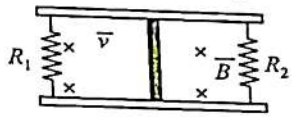
(a) 0 V (b) 2π V (c) 2 V (d) 1 V

37. The arm PQ of a rectangular conductor is moving from $x = 0$ to $x = 2b$ outwards and then inwards from $x = 2b$ to $x = 0$ as shown in the figure. A uniform magnetic field perpendicular to the plane is acting from $x = 0$ to $x = b$. Identify the graph the variation of different quantities with distance.
[20 July, 2021 (Shift-I)]



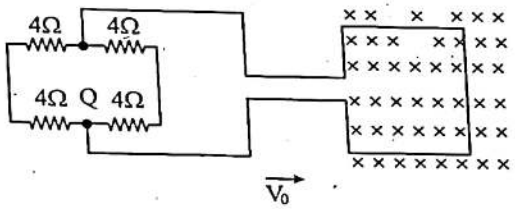
(a) A – Flux, B – emf, C – Power dissipated
(b) A – emf, B – Power dissipated, C – Flux
(c) A – Power dissipated, B – Flux, C – emf
(d) A – Flux, B – Power dissipated, C – emf

38. A conducting bar of length L is free to slide on two parallel conducting rails as shown in the figure.
[16 March, 2021 (Shift-I)]



Two resistors R_1 and R_2 are connected across the ends of the rails. There is a uniform magnetic field $\vec{B}$ pointing into the page. An external agent pulls the bar to the left at a constant speed v. The correct statement about the directions of induced currents I_1 and I_2 flowing throught R_1 and R_2 respectively is
(a) I_1 is in anticlockwise direction and I_2 is in clockwise direction
(b) Both I_1 and I_2 are in anticlockwise direction
(c) Both I_1 and I_2 are in clockwise direction
(d) I_1 is in clockwise direction and I_2 is in anticlockwise direction

39. A square loop of side 20 cm and resistance 1Ω is moved towards right with a constant speed v_0. The right arm of the loop is in a uniform magnetic field of 5T. The field is perpendicular to the plane of the loop and is going into it. The loop is connected to a network of resistors each of value 4. What should be the value of v_0 so that a steady current of 2 mA flows in the loop **[1 Sep, 2021 (Shift-II)]**

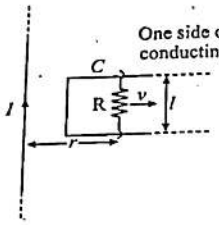


(a) 1 m/s (b) 10^2 m/s (c) 10^{-2} cm/s (d) 1 cm/s

@FAKE CBSE @RAJEEV VET

40. An infinitely long, straight wire carrying current I, one side opened rectangular loop and a conductor C with a sliding connector are located in the same plane as shown, in the figure. The connector has length l and resistance R. It slides to the right with a velocity v. The resistance of the conductor and the self inductance of the loop are negligible. The induced current in the loop, as a function of separation r, between the connector and the straight wire is

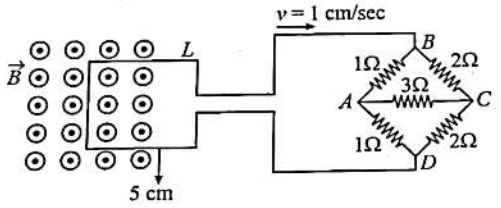
[5 Sep, 2020 (Shift-II)]



(a) $\frac{\mu_0}{4\pi}\frac{Ivl}{Rr}$ (b) $\frac{\mu_0}{\pi}\frac{Iv\ell}{Rr}$ (c) $\frac{\mu_0}{2\pi}\frac{Ivl}{Rr}$ (d) $\frac{2\mu_0}{\pi}\frac{Ivl}{Rr}$

41. The figure shows a square loop L of side 5 cm which is connected to a network of resistances. The whole setup is moving towards right with a constant speed of 1 cms^{-1}. At some instant, a part of L is in a uniform magnetic field of 1 T, perpendicular to the plane of the loop. If the resistance of L is 1.7Ω, the current in the loop at that instant will be close to

[12 April, 2019 (Shift-I)]



(a) 115 μA (b) 170 μA (c) 60 μA (d) 150 μA

42. A solid metal cube of edge length 2 cm is moving in a positive y-direction at a constant speed of 6 m/s. There is a uniform magnetic field of 0.1 T in the positive z-direction. The potential difference between the two faces of the cube perpendicular to the x-axis, is:

[10 Jan, 2019 (Shift-I)]

(a) 12 mV (b) 6 mV (c) 1 mV (d) 2 mV

Induced emf in a Rod, Ring, Disc Rotating in a Uniform Magnetic Field

43. A coil of 200 turns and area 0.20 m^2 is rotated at half a revolution per second and is placed in uniform magnetic field of 0.01 T perpendicular to axis of rotation of the coil. The maximum voltage generated in the coil is $\frac{2\pi}{\beta}$ volt. The value of β is _____.

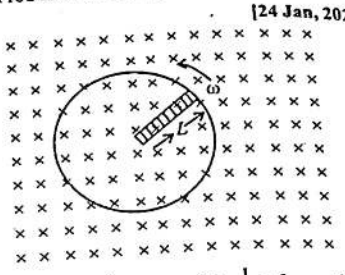
[1 Feb, 2024 (Shift-II)]

44. A rod of length 60 cm rotates with a uniform angular velocity 20 rad s^{-1} about its perpendicular bisector, in a uniform magnetic field 0.5 T. The direction of magnetic field is parallel to the axis of rotation. The potential difference between the two ends of the rod is _____ V.

[04 April, 2024 (Shift-II)]

45. A metallic rod of length 'L' is rotated with an angular speed of 'ω' normal to a uniform magnetic field 'B' about an axis passing through one end of rod as shown in figure. The induced emf will be:

[24 Jan, 2023 (Shift-II)]



(a) $\frac{1}{4}B^2L\omega$ (b) $\frac{1}{4}BL^2\omega$ (c) $\frac{1}{2}BL^2\omega$ (d) $\frac{1}{2}B^2L^2\omega$

46. The induced emf can be produced in a coil by

A. Moving the coil with uniform speed inside magnetic field
B. Moving the coil with non-uniform speed inside uniform magnetic field
C. Rotating the coil inside the uniform magnetic field
D. Changing the area of the coil inside the uniform magnetic field

Choose the correct answer from the options given below:

[6 April, 2023 (Shift-I)]

(a) B and D only (b) B and C only
(c) A and C only (d) C and D only

47. A 20 cm long metallic rod is rotated with 210 rpm about an axis normal to the rod passing through its one end. The other end of the rod is in contact with a circular metallic ring. A constant and uniform magnetic field 0.2 T parallel to the axis exists everywhere. The emf developed between the centre and the ring is _____ mV. Take $\pi = \frac{22}{7}$

[15 April, 2023 (Shift-I)]

48. A conducting circular loop is placed in a uniform magnetic field of 0.4 T with its plane perpendicular to the field. Somehow, the radius of the loop starts expanding at a constant rate of 1 mm/s. The magnitude of induced emf in the loop at an instant when the radius of the loop is 2 cm will be _____ μV.

[12 April, 2023 (Shift-I)]

49. A square shaped coil of area 70 cm^2 having 600 turns rotates in a magnetic field of 0.4 $Wb\ m^{-2}$, about an axis which is parallel to one of the side of the coil and perpendicular to the direction of field. If the coil completes 500 revolution in a minute, the instantaneous emf when the plane of the coil is inclined at 60° with the field, will be _____ V.

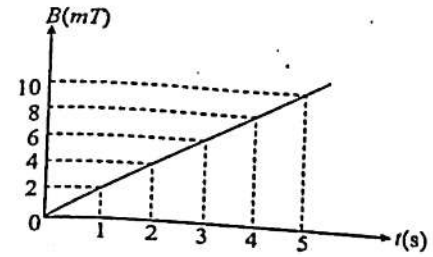
(Take $\pi = \frac{22}{7}$)

[1 Feb, 2023 (Shift-II)]

50. The magnetic field B crossing normally a square metallic plate of area 4 m^2 is changing with time as shown in figure. The magnitude of induced emf in the plate during $t = 2$ s to $t = 4$ s, is _____ mV

[11 April, 2023 (Shift-I)]

@FIKE_CBSE_K@RNEDUNET



51. A certain elastic conducting material is stretched into a circular loop. It is placed with its plane perpendicular to a uniform magnetic field of $B = 0.8\ T$. When released the radius of the loop starts shrinking at a constant rate of 2 cm/s. The induced emf in the loop at an instant when the radius of the loop is 10 cm will be _____ mV.

[29 Jan, 2023 (Shift-I)]

52. A metallic conductor of length 1m rotates in a vertical plane parallel to east-west direction about one of its end with angular velocity 5 rad/s. If the horizontal component of earth's magnetic field is 0.2×10^{-4} T, then emf induced between the two ends of the conductor is **[26 June, 2022 (Shift-II)]**

(a) 5 μV (b) 50 μV (c) 5 mV (d) 50 mV

53. A circular coil of 1000 turns each with area $1m^2$ is rotated about its vertical diameter at the rate of one revolution per second in a uniform horizontal magnetic field of 0.07 T. The maximum voltage generation will be _____V. **[24 June, 2022 (Shift-II)]**

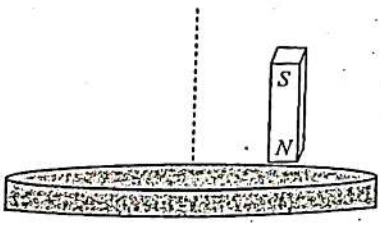
54. A planar loop of wire rotates in a uniform magnetic field. Initially at $t = 0$, the plane of the loop is perpendicular to the magnetic field. If it rotates with a period of 10 s about an axis in its plane then the magnitude of induced emf will be maximum and minimum, respectively at: **[7 Jan, 2020 (Shift-II)]**

(a) 5.0 s and 7.5 s (b) 5.0 s and 10.0 s
(c) 2.5 s and 7.5 s (d) 2.5 s and 5.0 s

55. A circular coil of radius 10 cm is placed in a uniform magnetic field of 3.0×10^{-5} T with its plane perpendicular to the field initially. It is rotated at constant angular speed about an axis along the diameter of coil and perpendicular to magnetic field so that it undergoes half of rotation in 0.2 s. The maximum value of emf induced (in μV) in the coil will be close to the integer _____. **[2 Sep, 2020 (Shift-I)]**

56. A light disc made of aluminium (a nonmagnetic material) is kept horizontally and is free to rotate about its axis as shown in the figure. A strong magnet is held vertically at a point above the disc away from its axis. On revolving the magnet about the axis of the disc, the disc will (figure is schematic and not drawn to scale)

[JEE Adv, 2020]



(a) Rotate in the direction opposite to the direction of magnet's motion.
(b) Rotate in the same direction as the direction of magnet's motion.
(c) Not rotate and its temperature will remain unchanged.
(d) Not rotate but its temperature will slowly rise.

Induced Electric Field

57. The source of time varying magnetic field may be

A. a permanent magnet
B. an electric field changing linearly with time
C. direct current
D. a decelerating charge particle
E. an antenna fed with a digital signal

Choose the correct answer from the options given below:

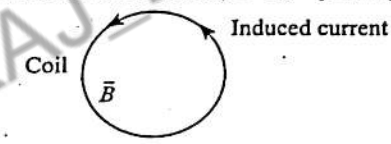
[13 April, 2023 (Shift-I)]

(a) D only (b) C and E only
(c) A only (d) B and D only

58. A circular conducting coil of radius 1 m being heated by the change of magnetic field $\vec{B}$ passing perpendicular to the plane in which the coil is laid. The resistance of the coil is $2\mu\Omega$. The magnetic field is slowly switched off such that its magnitude changes in time as $B = \frac{4}{\pi} \times 10^{-3} T\left(1 - \frac{t}{100}\right)$.

The energy dissipated by the coil before the magnetic field is switched off completely is $E =$ ____ mJ **[25 July, 2021 (Shift-I)]**

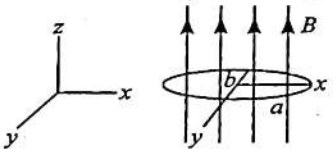
59. A coil is placed in a magnetic field as shown below: $B.A$ current is induced in the coil because $\vec{B}$ is: **[31 Aug, 2021 (Shift-II)]**



(a) Outward and decreasing with time
(b) Parallel to the plane of coil and decreasing with time
(c) Parallel to the plane of coil and increasing with time
(d) Outward and increasing with time

60. An elliptical loop having resistance R, of semi major axis a and semi minor axis b is placed in a magnetic field as shown in the figure. If the loop is rotated about the x-axis with angular frequency ω, the average power loss in the loop due to joule heating is:

[3 Sep, 2020 (Shift-I)]



(a) $\frac{\pi^2 a^2 b^2 B^2 \omega^2}{R}$ (b) Zero
(c) $\frac{\pi abB\omega}{R}$ (d) $\frac{\pi^2 a^2 b^2 B^2 \omega^2}{2R}$

61. A circular coil has moment of inertia 0.8 kg m² around any diameter and is carrying current to produce a magnetic moment of 20 Am². The coil is kept initially in a vertical position and it can rotate freely around a horizontal diameter. When a uniform magnetic field of 4 T is applied along the vertical, it starts rotating around its horizontal diameter. The angular speed the coil acquires after rotating by 60° will be **[4 Sep, 2020 (Shift-II)]**

(a) 10 rad s^{-1} (b) 10π rad s^{-1} (c) 20 rad s^{-1} (d) 20π rad s^{-1}

@JEE_CODE X @RAJ_EDUNET

62. A uniform magnetic field B exists in a direction perpendicular to the plane of a square loop made of a metal wire. The wire has a diameter of 4 mm and a total length of 30 cm. The magnetic field changes with time at a steady rate $dB/dt = 0.032\ Ts^{-1}$. The induced current in the loop is close to (Resistivity of the metal wire is $1.23 \times 10^{-8}\ \Omega m$)

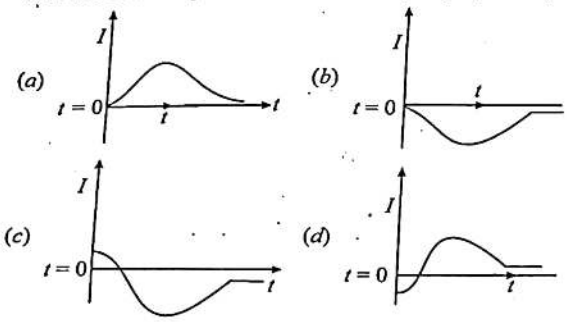
[3 Sep, 2020 (Shift-II)]

(a) 0.34 A (b) 0.61 A (c) 0.53 A (d) 0.43 A

63. A conducting circular loop made of a thin wire, has area $3.5 \times 10^{-3}\ m^2$ and resistance 10 Ω. It is placed perpendicular to a time dependent magnetic field $B(t) = (0.4\ T) \sin(50\ \pi t)$. The field is uniform in space. Then the net charge flowing through the loop during $t = 0$ s and $t = 10$ ms is close to **[9 Jan, 2019 (Shift-I)]**

(a) 14 mC (b) 7 mC (c) 21 mC (d) 6 mC

64. A very long solenoid of radius R is carrying current $I(t) = kte^{-\alpha t}(k > 0)$, as a function of time ($t \geq 0$). Counter clockwise current is taken to be positive. A circular conducting coil of radius $2R$ is placed in the equatorial plane of the solenoid and concentric with the solenoid. The current induced in the outer coil is correctly depicted, as a function of time by **[9 April, 2019 (Shift-II)]**

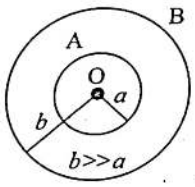


Self Inductance, Mutual Inductance & Magnetic Energy Density

65. Two coils have mutual inductance 0.002 H. The current changes in the first coil according to the relation $i = i_0 \sin \omega t$, where $i_0 = 5A$ and $\omega = 50\pi$ rad/s. The maximum value of emf in the second coil is $\frac{\pi}{\alpha}$ V. The value of α is _____. **[27 Jan, 2024 (Shift-I)]**

66. A small square loop of wire of side l is placed inside a large square loop of wire of side L ($L = l^2$). The loops are coplanar and their centers coinside. The value of the mutual inductance of the system is $\sqrt{x} \times 10^{-7}$ H, where $x =$ _____. **[31 Jan, 2024 (Shift-I)]**

67. Two conducting circular loops A and B are placed in the same plane with their centres coinciding as shown in figure. The mutual inductance between them is: **[05 April, 2024 (Shift-I)]**



(a) $\frac{\mu_0 \pi a^2}{2b}$ (b) $\frac{\mu_0}{2\pi} \cdot \frac{b^2}{a}$ (c) $\frac{\mu_0 \pi b^2}{2a}$ (d) $\frac{\mu_0}{2\pi} \cdot \frac{a^2}{b}$

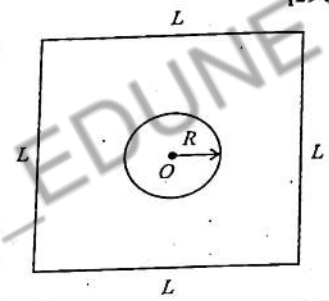
68. The current in an inductor is given by $I = (3t + 8)$ where t is in second. The magnitude of induced emf produced in the inductor is 12 mV. The self inductance of the inductor _____ mH. **[05 April, 2024 (Shift-II)]**

69. In a coil, the current changes form $-2A$ to $+2A$ in 0.2 s and induces an emf of 0.1 V. The selfinductance of the coil is: **[06 April, 2024 (Shift-II)]**

(a) 5 mH (b) 1 mH (c) 2.5 mH (d) 4 mH

70. When a coil is connected across a 20 V dc supply, it draws a current of 5 A. When it is connected across 20 V, 50 Hz ac supply, it draws a current of 4 A. The self inductance of the coil is _____ mH. (Take $\pi = 3$) **[09 April, 2024 (Shift-I)]**

71. Find the mutual inductance of the arrangement, when a small circular loop of wire of radius 'R' is placed inside a large square loop of wire of side L ($L >> R$). The loops are coplanar and their centres coincide: **[29 Jan, 2023 (Shift-I)]**



(a) $M = \frac{\sqrt{2}\mu_0 R^2}{L}$ (b) $M = \frac{2\sqrt{2}\mu_0 R}{L^2}$

(c) $M = \frac{2\sqrt{2}\mu_0 R^2}{L}$ (d) $M = \frac{\sqrt{2}\mu_0 R}{L^2}$

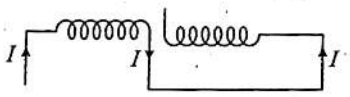
72. A 12 V battery connected to a coil of resistance 6Ω through a switch, drives a constant current in the circuit. The switch is opened in 1 ms. The emf induced across the coil is 20 V. The inductance of the coil is : **[15 April, 2023 (Shift-I)]**

(a) 5 mH (b) 12 mH (c) 8 mH (d) 10 mH

73. Two concentric circular coils with radii 1 cm and 1000 cm, and number of turns 10 and 200 respectively are placed coaxially with centers coinciding. The mutual inductance of this arrangement will be _____ $\times 10^{-8}$ H.. (Take, $\pi^2 = 10$) **[6 April, 2023 (Shift-II)]**

74. A coil has an inductance of 2H and resistance of 4Ω. A 10 V is applied across the coil. The energy stored in the magnetic field after the current has built up to its equilibrium value will be _____ $\times 10^{-2}$ J **[11 April, 2023 (Shift-II)]**

75. Two coils of self inductance L_1 and L_2 are connected in series combination having mutual inductance of the coils as M. The equivalent self inductance of the combination will be **[26 June, 2022 (Shift-II)]**

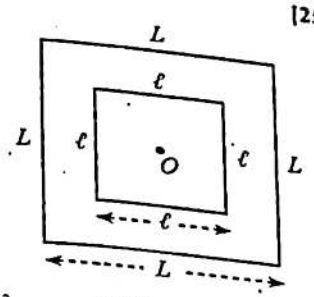


@TAKE_CBSE_X @RAJ_EDUNET

(a) $\frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{M}$ (b) L_1+L_2+M

(c) L_1+L_2+2M (d) L_1+L_2-2M

76. A small square loop of wire of side l is placed inside a large square loop of wire. $L(L>>l)$. Both loops are coplanar and their centres coincide at point O as shown in figure. The mutual inductance of the system is: **[25 July, 2022 (Shift-I)]**



(a) $\frac{2\sqrt{2}\mu_0 L^2}{\pi\ell}$ (b) $\frac{\mu_0\ell^2}{2\sqrt{2}\pi L}$ (c) $\frac{2\sqrt{2}\mu_0\ell^2}{\pi L}$ (d) $\frac{\mu_0 L^2}{2\sqrt{2}\pi\ell}$

77. A coil is placed in a time varying magnetic field. If the number of turns in the coil were to be halved and the radius of wire doubled, the electrical power dissipated due to the current induced in the coil would be: (Assume the coil to be short circuited.) **[28 June, 2022 (Shift-II)]**

(a) Halved (b) Quadrupled

(c) The same (d) Doubled

78. The current in a coil of self inductance 2.0 H is increasing according to $I=2\sin(t^2)$ A. The amount of energy spent during the period when current changes from 0 to 2 A is_____J. **[25 June, 2022 (Shift-I)]**

79. A small square loop of side 'a' and one turn is placed inside a larger square loop of side b and one turn ($b >> a$). The two loops are coplanar with their centres coinciding. If a current I is passed in the square loop of side 'b', then the coefficient of mutual inductance between the two loops is: **[31 Aug, 2021 (Shift-I)]**

(a) $\frac{\mu_0}{4\pi}\frac{8\sqrt{2}}{b}$ (b) $\frac{\mu_0}{4\pi}8\sqrt{2}\frac{b^2}{a}$ (c) $\frac{\mu_0}{4\pi}\frac{8\sqrt{2}}{a}$ (d) $\frac{\mu_0}{4\pi}8\sqrt{2}\frac{a^2}{b}$

80. In a fluorescent lamp choke (a small transformer) 100 V of reverse voltage is produced when the choke current changes uniformly from 0.25 A to 0 in a duration of 0.025 ms. The self-inductance of the choke (in mH) is estimated to be _____. **[9 Jan, 2020 (Shift-I)]**

81. Two coils P and Q are separated by some distance. When a current of $3A$ flows through coil P a magnetic flux of 10^{-3} Wb passes through Q. No current is passed through Q. When no current passes through P and a current of $2A$ passes through Q, the flux through P is: **[9 April, 2019 (Shift-II)]**

(a) 6.67×10^{-3} Wb (b) 6.67×10^{-4} Wb

(c) 3.67×10^{-4} Wb (d) 3.67×10^{-3} Wb

82. The total number of turns and cross-section area in solenoid is fixed. However, its length L is varied by adjusting the separation between windings. The inductance of solenoid will be proportional to: **[9 April, 2019 (Shift-I)]**

(a) $1/L$ (b) L (c) $1/L^2$ (d) L^2

83. There are two long co-axial solenoids of same length l. The inner and outer coils have radii r_1 and r_2 and number of turns per unit length n_1 and n_2 respectively. The ratio of mutual inductance to the self-inductance of the inner-coil is **[11 Jan, 2019 (Shift-I)]**

(a) $\frac{n_1}{n_2}$ (b) $\frac{n_2 r_1}{n_1 r_2}$ (c) $\frac{n_2 r_2^2}{n_1 r_1^2}$ (d) $\frac{n_2}{n_1}$

84. The self produced emf of a coil is 25 volts. When the current in it is changed at uniform rate from 10 A to 25 A in 1 s, the change in the energy of the inductance is : **[10 Jan, 2019 (Shift-II)]**

(a) 740 J (b) 437.5 J (c) 540 J (d) 637.5 J

85. A copper wire is wound on a wooden frame, whose shape is that of an equilateral triangle. If the linear dimension of each side of the frame is increased by a factor of 3, keeping the number of turns of the coil per unit length of the frame the same, then self inductance of the coil **[11 Jan, 2019 (Shift-II)]**

(a) Decreases by a factor of 9 (b) Increases by a factor of 27

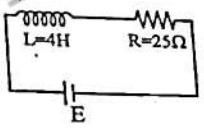
(c) Increases by a factor of 3 (d) Decreases by a factor of $9\sqrt{3}$

L-R Circuit, L-C Oscillator

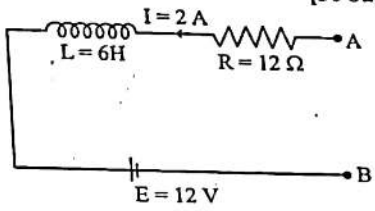
86. A capacitor of capacitance 100 μF is charged to a potential of 12V and connected to a 6.4 mH inductor to produce oscillations. The maximum current in the circuit would be: **[29 Jan, 2024 (Shift-I)]**

(a) 3.2A (b) 1.5A (c) 2.0A (d) 1.2A

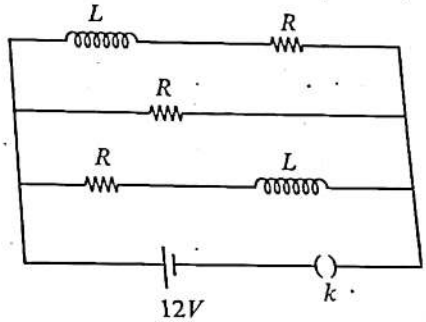
87. In the given figure, an inductor and a resistor are connected in series with a battery of emf E volt. $\frac{E^a}{2b}$ J/s represents the maximum rate at which the energy is stored in the magnetic field (inductor). The numerical value of $\frac{b}{a}$ will be ____. **[13 April, 2023 (Shift-I)]**



88. As per the given figure, if $\frac{dI}{dt}=-1\,A/s$ then the value of V_{AB} at this instant will be ____ V. **[30 Jan, 2023 (Shift-I)]**



89. Three identical resistors with resistance $R=12\Omega$ and two identical inductors with self inductance L = 5 mH are connected to an ideal battery with emf of 12 V as shown in figure. The current through the battery long after the switch has been closed will be _____A. **[24 Jan, 2023 (Shift-II)]**



@FIITJEE_GBSER @RAJ_FIITJEE

90. A coil of inductance $1H$ and resistance 100Ω is connected to a battery of $6\ V$. Determine approximately:

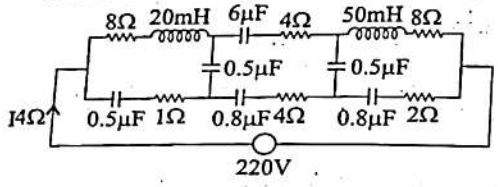
A. The time elapsed before the current acquires half of its steady - state value.

B. The energy stored in the magnetic field associated with the coil at instant 15 ms after the circuit is switched on. (Given $\ln 2 = 0.693$, $e^{-3/2} = 0.25$) **[29 July, 2022 (Shift-I)]**

(a) $t = 10ms$; $U = 2mJ$ (b) $t = 10ms$; $U = 1mJ$
(c) $t = 7ms$; $U = 1mJ$ (d) $t = 7ms$; $U = 2mJ$

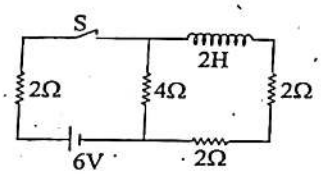
91. A 10 Ω, 20 mH coil carrying constant current is connected to a battery of 20 V through a switch. Now after switch is opened current becomes zero in 100 μs. The average e.m.f. induced in the coil is _____ V. **[26 June, 2022 (Shift-I)]**

92. The effective current I in the given circuit at very high frequencies will be _____ A.



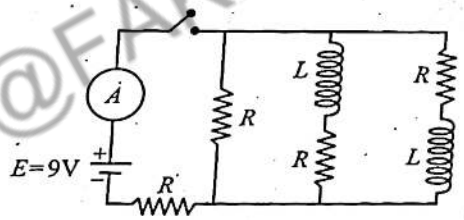
[26 July, 2022 (Shift-I)]

93. For the given circuit the current through battery of 6 V just after closing the switch 'S' will be _____ A. **[28 July, 2022 (Shift-II)]**



94. A coil of inductance 2 H having negligible resistance is connected to a source of supply whose voltage is given by $V = 3t$ volt, (where t is in second). If the voltage is applied when $t = 0$, then the energy stored in the coil after 4 s is _____ J. **[25 Feb, 2021 (Shift-I)]**

95. Figure shows a circuit that contains four identical resistors with resistance $R = 2.0\Omega$, two identical inductors with inductance $L = 2.0$ mH and an ideal battery with emf $E = 9$ V. The current 'i' just after switch 'S' is closed will be: **[24 Feb, 2021 (Shift-II)]**



(a) 2.25 A (b) 3.0 A (c) 9 A (d) 3.37 A

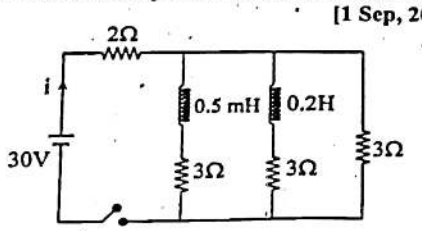
96. An inductor coil stores 64 J of magnetic field energy and dissipates energy at the rate of 640 W when a current of 8 A is passed through it. If this coil is joined across an ideal battery, find the time constant of the circuit in seconds : **[26 Aug, 2021 (Shift-I)]**

(a) 0.8 (b) 0.2 (c) 0.125 (d) 0.4

97. A solenoid of 1000 turns per metre has a core with relative permeability 500. Insulated windings of the solenoid carry an electric current of 5 A. The magnetic flux density produced by the solenoid is:(Permeability of free space is $4\pi \times 10^{-7}$) **[17 March, 2021 (Shift-I)]**

(a) π T (b) $2 \times 10^{-3}\ \pi$ T
(c) $10^{-4}\ \pi$ T (d) $\frac{\pi}{5}$ T

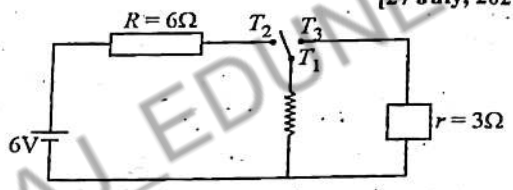
98. For the given circuit the current i through the battery when the key in closed and the steady state has been reached is _____. **[1 Sep, 2021 (Shift-II)]**



(a) 25 A (b) 0 A (c) 6 A (d) 10 A

99. Consider an electrical circuit containing a two way switch 'S'. Initially S is open and then T_1 is connected to T_2. As the current in $R = 6\Omega$ attains a maximum value of steady state level, T_1 is disconnected from T_2 and immediately connected to T_3. Potential drop across $r = 3\Omega$ resistor immediately after T_1 is connected to T_3 is _____ V. (Round off to the Nearest Integer)

[27 July, 2021 (Shift-I)]



100. The time taken for the magnetic energy to reach 25% of its maximum value, when a solenoid of resistance R, and inductance L is connected to a battery, is: **[18 March, 2021 (Shift-II)]**

(a) $\frac{L}{R}\ell n\,(2)$ (b) $\frac{L}{R}\ell n\,(10)$ (c) Infinite (d) $\frac{L}{R}\ell n\,(5)$

101. An inductor of 10 mH is connected to a 20 V battery through a resistor of 10k Ω and a switch. After a long time, when maximum current is set up in the circuit, the current is switched off. The current in the circuit after 1μs is $\frac{x}{100}$ mA. Then x is equal to _____. (Take $e^{-1} = 0.37$)

[25 July, 2021 (Shift-I)]

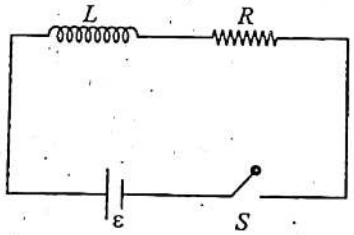
102. An emf of 20V is applied at time $t = 0$ to a circuit containing in series 10mH inductor and 5Ω resistor. The ratio of the currents at time $t = \infty$ and at $t = 40\ s$ is close to: (take $e^2 = 7.389$)

[7 Jan, 2020 (Shift-II)]

(a) 1.06 (b) 0.84 (c) 1.46 (d) 1.15

103. As shown in the figure, a battery of emf ε is connected to an inductor L and resistance R in series. The switch is closed at $t = 0$. The total charge that flows from the battery, between $t = 0$ and $t = t_c$ (t_c is the time constant of the circuit) is:

[8 Jan, 2020 (Shift-II)]

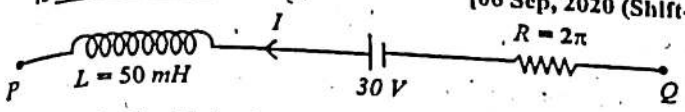


@FAKE_SSC_X @RAJ_EDUNET

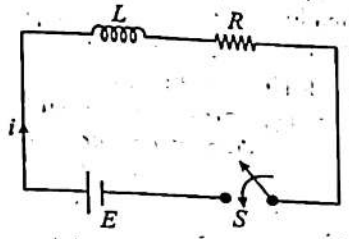
(a) $\frac{\varepsilon L}{eR^2}$ (b) $\frac{\varepsilon L}{R^2}\left(1-\frac{1}{e}\right)$

(c) $\frac{\varepsilon R}{eL^2}$ (d) $\frac{\varepsilon L}{R^2}$

104. A part of complete circuit is shown in the figure. At some instant, the value of current I is 1 A and it is decreasing at a rate of 10^3 As^{-1}. The value of the potential difference $V_P - V_Q$, (in volts) at that instant, is _____. [06 Sep, 2020 (Shift-I)]



105. Consider the LR circuit shown in the figure. If the switch S is closed at $t = 0$ then the amount of charge that passes through the battery between $t = 0$ and $t = \frac{L}{R}$ is [12 April, 2019 (Shift-II)]



(a) $\frac{EL}{7.3R^2}$ (b) $\frac{EL}{2.7R^2}$ (c) $\frac{7.3EL}{R^2}$ (d) $\frac{2.7EL}{R^2}$

106. A coil of self inductance 10 mH and resistance 0.1Ω is connected through a switch to a battery of internal resistance 0.9 Ω. After the switch is closed the time taken for the current to attain 80% of the saturation values is: [take in 5 = 1.6] [10 April, 2019 (Shift-II)]

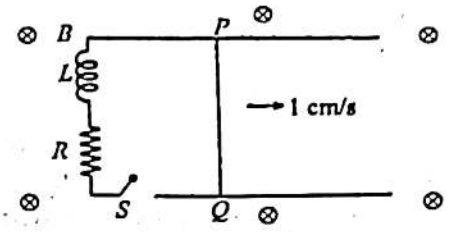
(a) 0.016 s (c) 0.324 s (b) 0.002 s (d) 0.103 s

107. A 10 cm long perfectly conducting wire PQ is moving, with a velocity 1cm/s on a pair of horizontal rails of zero resistance. One side of the rails is connected to an inductor L =.1 mH and a resistance $R = 1\Omega$ as shown in figure. The horizontal rails, L and R lie in the same plane with a uniform magnetic field $B = 1$ T perpendicular to the plane. If the key S is closed at certain instant, the current in the circuit after 1 millisecond is $x \times 10^{-3}$ A, where the value of x is_____.

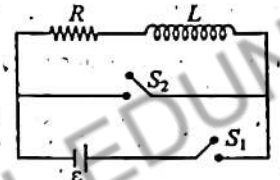
[Assume the velocity of wire PQ remains constant (1 cm/s) after key S is closed.

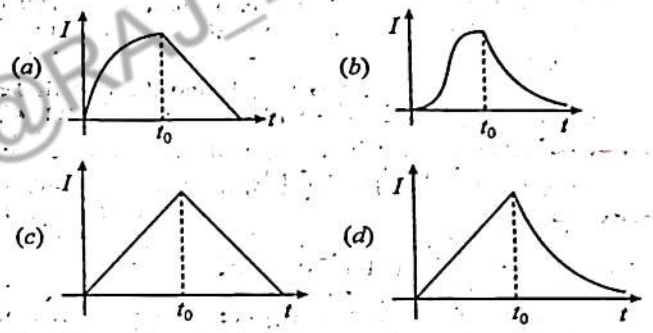
Given: $e^{-1} = 0.37$, where e is base of the natural logarithm]

[JEE Adv, 2019]



108. In the circuit shown, The switch S_1 is closed at time $t = 0$ and the switch S_2 is kept open. At some later time (t_0) the switch S_1 is opened and S_2 is closed. The behaviour of the current I as a function of time 't' is [11 Jan, 2019 (Shift-I)]





@TAKE_OFF_X @RAJ_EDUNET

JEE-Advanced

Magnetic Flux and Faraday'S Laws of EMI

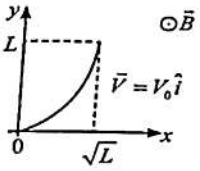
Single Correct

1. An infinitely long cylinder is kept parallel to a uniform magnetic field B directed along positive Z-axis. The direction of induced current as seen from the Z-axis will be (IIT-JEE 2005)
   (a) clockwise of the +ve Z-axis
   (b) anti-clockwise of the +ve Z-axis
   (c) zero
   (d) along the magnetic field

2. A short-circuited coil is placed in a time varying magnetic field. Electrical power is dissipated due to the current induced in the coil. If the number of turns were to be quadrupled (four times) and the wire radius halved, the electrical power dissipated would be (IIT-JEE 2002)
   (a) halved (b) the same (c) doubled (d) quadrupled

Multiple Correct

3. A conducting wire of parabolic shape, initially $y = x^2$. is moving with velocity $\vec{V} = V_0\hat{i}$ in a non-uniform magnetic field $\vec{B} = B_0\left(1+\left(\frac{y}{L}\right)^{\beta}\right)\hat{k}$, as shown in figure. If V_0, B_0, L and β are positive constants and $\Delta\phi$ is the potential difference developed between the ends of the wire, then the correct statement(s) is/are: C-6 W-16 UA-49 PC-30 (JEE Adv. 2019)



(a) $|\Delta\phi| = \frac{1}{2}B_0V_0L$ for $\beta = 0$

(b) $|\Delta\phi| = \frac{4}{3}B_0V_0L$ for $\beta = 2$

(c) $|\Delta\phi|$ remains the same if the parabolic wire is replaced by a straight wire, $y = x$ initially, of length $\sqrt{2}L$

(d) $|\Delta\phi|$ is proportional to the length of the wire projected on the y-axis.

Subjective

4. A thermocol vessel contains 0.5 kg of distilled water at 30°C. A metal coil of area 5×10^{-3} m², number of turns 100, mass 0.06 kg and resistance 1.6 Ω is lying horizontally at the bottom of the vessel. A uniform time varying magnetic field is setup to pass vertically through the coil at time $t = 0$. The field is first increased from 0 to 0.8 T at a constant rate between 0 and 0.2 s and then decreased to zero at the same rate between 0.2 and 0.4 s.

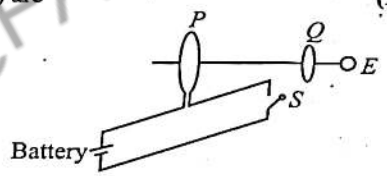
The cycle is repeated 12000 times. Make sketches of the current through the coil and the power dissipated in the coil as a function of time for the first two cycles. Clearly indicate the magnitudes of the quantities on the axes. Assume that no heat is lost to the vessel or the surroundings. Determine the final temperature of the water under thermal equilibrium.

Specific heat of metal = 500 J/kg–K and the specific heat of water = 4200 J/kg–K. Neglect the inductance of coil. **(IIT-JEE 2000)**

Lenz's Law

Single Correct

5. As shown in the figure, P and Q are two coaxial conducting loops separated by some distance. When the switch S is closed, a clockwise current I_P flows in P (as seen by E) and an induced current I_{Q_1} flows in Q. The switch remains closed for a long time. When S is opened, a current I_{Q_2} flows in Q. Then the direction I_{Q_1} and I_{Q_2} (as seen by E) are **(IIT-JEE 2002)**



(a) respectively clockwise and anti-clockwise
(b) both clockwise
(c) both anti-clockwise
(d) respectively anti-clockwise and clockwise

6. Two identical circular loops of metal wire are lying on a table without touching each other. Loop A carries a current which increases with time. In response, the loop B **(IIT-JEE 1999)**
(a) remains stationary
(b) is attracted by the loop A
(c) is repelled by the loop A
(d) rotates about its CM, with CM fixed.

Comprehension Based/Passage Based

Direction (Q. 7 to 9): Modern trains are based on Maglev technology in which trains are magnetically leviated, which runs its EDS Maglev system. There are coils on both sides of wheels. Due to motion of train, current induces in the coil of track which levitate it. This is in accordance with Lenz's law. If trains lower down then due to Lenz's law a repulsive force increases due to which train gets uplifted and if it goes much high, then there is a net downward force due to gravity. The advantage of Maglev train is that there is no friction between the train and the track, thereby reducing power consumption and enabling the train to attain very high speeds. Disadvantage of Maglev train is that as it slows down the electromagnetic forces decreases and it becomes difficult to keep it leviated and as it moves forward according to Lenz's law, there is an electromagnetic drag force. **(IIT-JEE 2006)**

7. What is the advantage of this system?
(a) No friction hence no power consumption
(b) No electric power is used
(c) Gravitation force is zero
(d) Electrostatic force draws the train

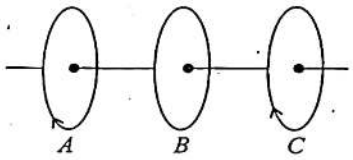
8. What is the disadvantage of this system ?
(a) Train experiences upward force according to Lenz's law
(b) Friction force create a drag on the train
(c) Retardation
(d) By Lenz's law train experience a drag

9. Which force causes the train to elevate up ?
(a) Electrostatic force
(b) Time varying electric field
(c) Magnetic force
(d) Induced electric field

Subjective

10. In a straight conducting wire, a constant current is flowing from left to right due to a source of emf. When the source is switched off, the direction of the induced current in the wire will be..... **(IIT-JEE 1993)**

11. Three identical closed coils A, B and C are placed with their planes parallel to one another. Coils A and C carry equal currents as shown in figure. Coils B and C are fixed in position and coil A is moved towards B with uniform motion. Is there any induced current in B? If no, give reasons. If yes, mark the direction of the induced current in the diagram. **(IIT JEE 1982)**



Induced Emf in a Moving Rod in Uniform Magnetic Field

Single Correct

12. A metal rod moves at a constant velocity in a direction perpendicular to its length. A constant uniform magnetic field exists in space in a direction perpendicular to the rod as well as its velocity. Select the correct statement (s) from the following. **(IIT-JEE 1998)**

@FAMOUSCBSE X @RAJEDUNET

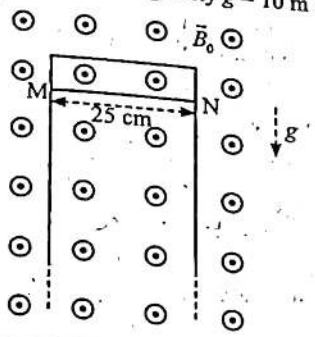
(a) The entire rod is at the same electric potential.
(b) There is an electric field in the rod.
(c) The electric potential is highest at the center of the rod and decreases towards its ends.
(d) The electric potential is lowest at the center of the rod and increases towards its ends.

Match the Column

13. A thin conducting rod MN of mass 20 gm, length 25 cm and resistance 10Ω is held on frictionless, long, perfectly conducting vertical rails as shown in the figure. There is a uniform magnetic field $B_0 = 4$ T directed perpendicular to the plane of the rod-rail arrangement. The rod is released from rest at time $t = 0$ and it moves down along the rails. Assume air drag is negligible. Match each quantity in List-I with an appropriate value from List-II, and choose the correct option.

C-20.74 W-22.95 UA-56.31 (JEE Adv. 2023)

[Given: The acceleration due to gravity $g = 10\ m\ s^{-2}$ and $e^{-1} = 0.4$]



List-I		List-II	
(P)	At $t = 0.2$ s, the magnitude of the induced emf in Volt	(1)	0.07
(Q)	At $t = 0.2$ s, the magnitude of the magnetic force in Newton	(2)	0.14
(R)	At $t = 0.2$ s, the power dissipated as heat in Watt	(3)	1.20
(S)	The magnitude of terminal velocity of the rod in $m\ s^{-1}$	(4)	0.12
		(5)	2.00

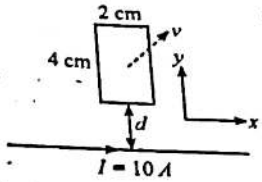
(a) P → 5, Q → 2, R → 3, S → 1
(b) P → 3, Q → 1, P → 4, S → 5
(c) P → 4, Q → 3, R → 1, S → 2
(d) P → 3, Q → 4, R → 2, S → 5

Numerical Types/Integer Types

14. A rectangular conducting loop of length 4 cm and width 2 cm is in the xy-plane, as shown in the figure. It is being moved away from a thin and long conducting wire along the direction $\frac{\sqrt{3}}{2}\hat{x}+\frac{1}{2}\hat{y}$ with a constant speed v. The wire is carrying a steady current $I = 10$ A in the positive x-direction. A current of 10 μA flows through the loop when it is at a distance $d = 4$ cm from the wire. If the resistance of the loop is 0.1 Ω, then the value of v is _____ ms^{-1}.

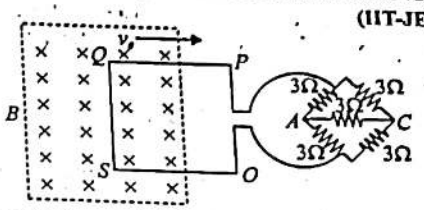
[Given: The permeability of free space $\mu_0 = 4\pi \times 10^{-7}\ NA^{-2}$]

C-9.8 W-58.36 UA-31.84 (JEE Adv. 2023)



15. A square metal wire loop of side 10cm and resistance 1Ω is moved with a constant velocity v_0 in a uniform magnetic field of induction $B = 2\ Wb/m^2$ as shown in the figure. The magnetic field lines are perpendicular to the plane of the loop (directed into the paper). The loop is connected to a network of resistors each of value 3Ω.

(IIT-JEE 1983)



What should be the speed of the loop so as to have a steady current of in the loop? Give the direction of current in the loop.

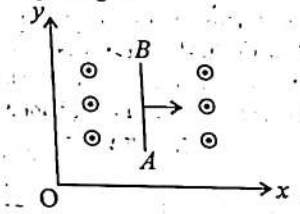
16. The two rails of a railway track, insulated from each other and the ground, are connected to a millivoltmeter. What is the reading of the millivoltmeter when a train travels at a speed of $180 km/h$ along the track given that the vertical components of earth's magnetic field is $0.2 \times 10^{-4}\ Wb/m^2$ and the rails are separated by $1m$? Track is South to North.

(IIT-JEE 1981)

True/False

17. A conducting rod AB moves parallel to the X-axis in a uniform magnetic field pointing in the positive z-direction. The end A of the rod gets positively charged.

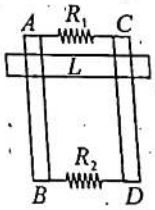
(IIT-JEE 1987)



Subjective

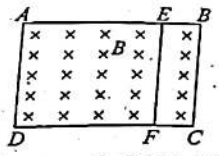
18. Two parallel vertical metallic rails AB and CD are separated by $1m$. They are connected at two ends by resistances R_1 and R_2 as shown in figure. A horizontal metallic bar of mass $0.2kg$ slides without friction vertically down the rails under the action of gravity. There is a uniform horizontal magnetic field of $0.6T$ perpendicular to the plane of the rails. It is observed that when the terminal velocity is attained, the powers dissipated in R_1 and R_2 are $0.7W$ and $1.2W$ respectively. Find the terminal velocity of the bar L and the values of R_1 and R_2.

(IIT-JEE 1994)



@FAKE_CRUSH @RAJ_EDUCATE

19. A rectangular frame $ABCD$, made of a uniform metal wire, has a straight connection between E and F made of the same wire, as shown in figure. $AEFD$ is a square of side 1m and $EB = FC = 0.5$m. The entire circuit is placed in a steadily increasing uniform magnetic field directed into the plane of the paper and normal to it. **(IIT-JEE 1993)**

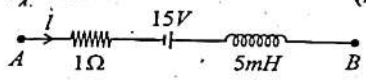


The rate of change of the magnetic field is $1T/s$. The resistance per unit length of the wire is $1\Omega/m$. Find the magnitudes and directions of the currents in the segments AE, BE and EF.

Circuit Problems With Dynamics

Numerical Types/Integer Types

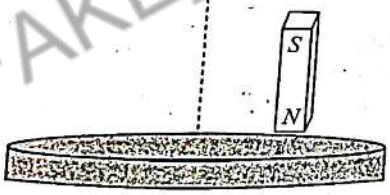
20. The network shown in figure is part of a complete circuit. If at a certain instant the current (I) is $5A$ and is decreasing at a rate of 10^3 A/s, then $V_B - V_A = $ ....V **(IIT-JEE 1997)**



Induced Emf in a Rod, Ring, Disc Rotating in a Uniform Magnetic Field

Single Correct

21. A light disc made of aluminium (a nonmagnetic material) is kept horizontally and is free to rotate about its axis as shown in the figure. A strong magnet is held vertically at a point above the disc away from its axis. On revolving the magnet about the axis of the disc, the disc will (figure is schematic and not drawn to scale) **C-11.7 W-53.2 UA-35.1 (JEE Adv. 2020)**



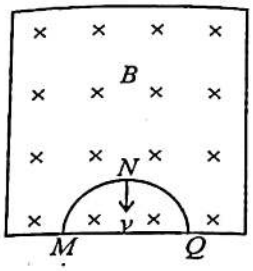
(a) Rotate in the direction opposite to the direction of magnet's motion.

(b) Rotate in the same direction as the direction of magnet's motion.

(c) Not rotate and its temperature will remain unchanged.

(d) Not rotate but its temperature will slowly rise.

22. A thin semi circular conducting ring of radius R is falling with its plane vertical in a horizontal magnetic induction B. At the position MNQ the speed of the ring is v and the potential difference developed across the ring is **(IIT-JEE 1996)**



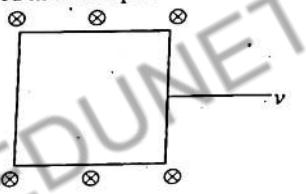
(a) $Bv\pi R^2/2$ and M is at higher potential

(b) πBRv and Q is at higher potential

(c) $2BRv$ and Q is at higher potential

(d) When it is just about to move out:

23. A conducting square loop of side L and resistance R moves in its plane with a uniform velocity v perpendicular to one of its sides. A magnetic induction B, constant in time and space, pointing perpendicular to and into the plane of the loop exists everywhere. The current induced in the loop is **(IIT-JEE 1989)**



(a) $\frac{Blv}{R}$ clockwise

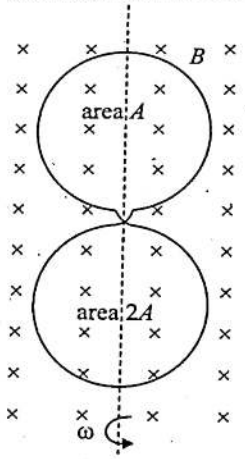
(b) $\frac{Blv}{R}$ anti-clockwise

(c) $2\frac{Blv}{R}$ anti-clockwise

(d) Zero

Multiple Correct

24. A circular insulated copper wire loop is twisted to form two loops of area A and $2A$ as shown in the figure. At the point of crossing the wires remain electrically insulated from each other. The entire loop lies in the plane (of the paper). A uniform magnetic field B points into the plane of the paper. At $t = 0$, the loop starts rotating about the common diameter as axis with a constant angular velocity ω in the magnetic field. Which of the following options is/are correct? **C-9.49 W-38.54 UA-38.44 PC-13.53 (JEE Adv. 2017)**



@FAKE_CBSE_X @RAJ_EDUNET

(a) The emf induced in the loop is proportional to the sum of the areas of the two loops.

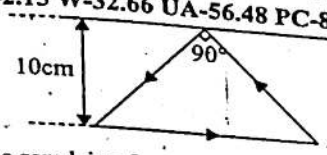
(b) The rate of change of the flux is maximum when the plane of the loops is perpendicular to plane of the paper.

(c) The net emf induced due to both the loops is proportional to $\cos\omega t$.

(d) The amplitude of the maximum net emf induced due to both the loops is equal to the amplitude of maximum emf induced in the smaller loop alone.

25. A conducting loop in the shape of a right angled isosceles triangle of height $10cm$ is kept such that the $90°$ vertex is very close to an infinitely long conducting wire (see the figure). The wire is electrically insulated from the loop. The hypotenuse of the triangle is parallel to the wire. The current in the triangular loop is in counterclockwise direction and increased at a constant rate of $10As^{-1}$. Which of the following statement(s) is/are true?

C-2.15 W-32.66 UA-56.48 PC-8.71 (JEE Adv. 2016)



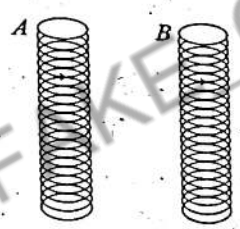
(a) There is a repulsive force between the wire and the loop.

(b) If the loop is rotated at a constant angular speed about the wire, an additional emf of $\left(\frac{\mu_0}{\pi}\right)$ volt is induced in the wire.

(c) The magnitude of induced emf in the wire is $\left(\frac{\mu_0}{\pi}\right)$ volt.

(d) The induced current in the wire is in opposite direction to the current along the hypotenuse

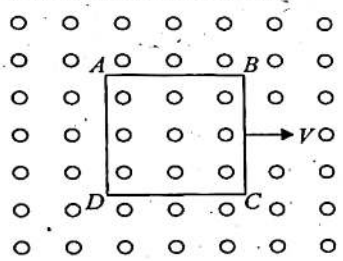
26. Two metallic rings A and B, identical in shape and size but having different resistivities ρ_A and ρ_B, are kept on top of two identical solenoids as shown in the figure. When current I is switched on in both the solenoids in identical manner, the rings A and B jump to heights h_A and h_B, respectively, with $h_A > h_B$. The possible relation(s) between their resistivities and their masses m_A and m_B is/are (IIT-JEE2009)



(a) $\rho_A > \rho_B$ and $m_A = m_B$ (b) $\rho_A < \rho_B$ and $m_A = m_B$

(c) $\rho_A > \rho_B$ and $m_A > m_B$ (d) $\rho_A < \rho_B$ and $m_A < m_B$

27. A metallic square loop $ABCD$ is moving in its own plane with velocity v in a uniform magnetic field perpendicular to its plane as shown in the figure: Electric field is induced (IIT-JEE 2001)



(a) in AD, but not in BC (b) in BC, but not in AD

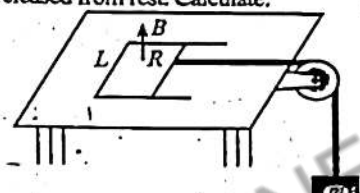
(c) neither in AD nor in BC (d) in both AD and BC

True/False

28. A coil of metal wire is kept stationary in a non-uniform magnetic field. An emf is induced in the coil. (IIT-JEE 1986)

Subjective

29. A pair of parallel horizontal conducting rails of negligible resistance shorted at one end is fixed on a table. The distance between the rails is L. A conducting massless rod of resistance R can slide on the rails frictionlessly. The rod is tied to a massless string which passes over a pulley fixed to the edge of the table. A mass m tied to the other end of the string hangs vertically. A constant magnetic field B exists perpendicular to the table. If the system is released from rest. Calculate: (IIT-JEE 1997)



(a) the terminal velocity achieved by the rod, and

(b) the acceleration of the mass at the instant when the velocity of the rod is half the terminal velocity

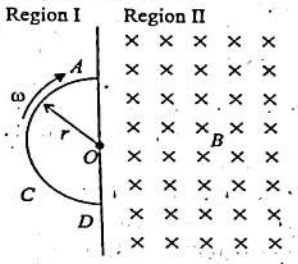
30. Space is divided by the line AD into two regions. Region I is field free and the region II has a uniform magnetic field B directed into the plane of the paper. ACD is a semicircular conducting loop of radius r with centre at O, the plane of the loop being in the plane of the paper.

The loop is now made to rotate with a constant angular velocity ω about an axis passing through O and perpendicular to the plane of the paper. The effective resistance of the loop is R. (IIT-JEE 1985)

(a) Obtain an expression for the magnitude of the induced current in the loop.

(b) Show the direction of the current when the loop is entering into the region II.

(c) Plot a graph between the induced current and the time of rotation for two periods of rotation.

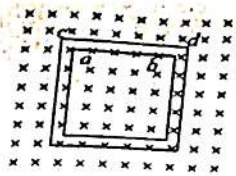


Fixed Loop in a Time Varying Magnetic Field & Induced Electric Field

Single Correct

31. The figure shows certain wire segments joined together to form a coplanar loop. The loop is placed in a perpendicular magnetic field in the direction going into the plane of the figure. The magnitude of the field increases with time. I_1 and I_2 are the currents in the segments ab and cd. Then, (IIT-JEE 2009)

@FREE_CBSE_GUIDE_NET

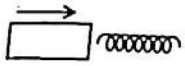


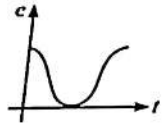
(a) $I_1 > I_2$ (b) $I_1 < I_2$

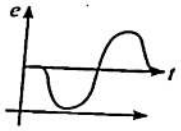
(c) I_1 is in the direction ba and I_2 is in the direction cd.

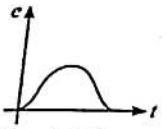
(d) I_1 is in the direction ba and I_2 is in the direction dc.

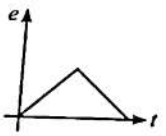
32. The variation of induced emf (e) with time (t) in a coil if a short bar magnet is moved along its axis with a constant velocity is best represented as **(IIT-JEE 2004)**



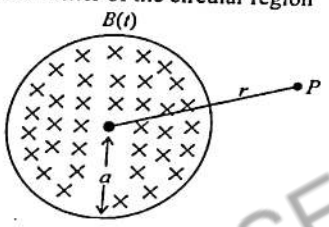
(a) 

(b) 

(c) 

(d) 

33. A uniform but time-varying magnetic field $B(t)$ exists in a circular region of radius a and is directed into the plane of the paper as shown. The magnitude of the induced electric field at point P at a distance r from the center of the circular region **(IIT-JEE 2000)**



(a) Is zero (b) Decreases as $\frac{1}{r}$

(c) Increases as r (d) Decreases as $\frac{1}{r^2}$

34. A circular loop of radius R, carrying current I, lies in $x-y$ plane with its centre at origin. The total magnetic flux through $x-y$ plane is **(IIT-JEE 1999)**

(a) directly proportional to I.

(b) directly proportional to R.

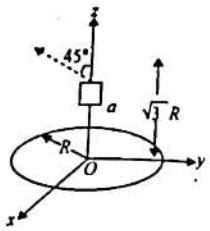
(c) inversely proportional to R.

(d) zero

Numerical Types/Integer Types

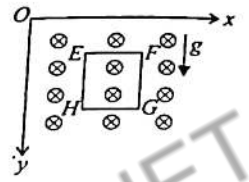
35. A circular wire loop of radius R is placed in the $x-y$ plane centred at the origin O. A square loop of side a($a << R$) having two turns is placed with its centre at $z = \sqrt{3}R$ along the axis of the circular wire loop, as shown in figure. The plane of the square loop makes an angle of 45° with respect to the -axis.

If the mutual inductance between the loops is given by $\frac{\mu_0 a^2}{2^{p/2}R}$, then the value of p is **C-4.69 W-78.65 UA-16.66 (IIT-JEE 2012)**



Subjective

36. A magnetic field $B = (B_0 y / a)\hat{k}$ is acting into the paper in the $+z$ direction. B_0 and a are positive constants. A square loop $EFGH$ of side a, mass m and resistance R in $x-y$ plane starts falling under the influence of gravity. Note the directions of x and y in the figure. Find **(IIT-JEE 1999)**

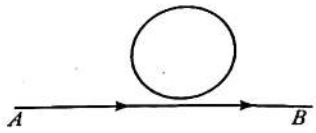


(a) the induced current in the loop and indicate its direction.

(b) the total Lorentz force acting on the loop and indicate its direction.

(c) an expression for the speed of the loop $v(t)$ and its terminal velocity.

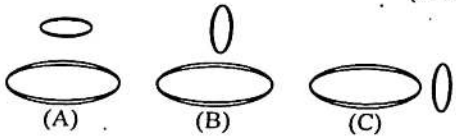
37. A current from A to B is increasing in magnitude. What is the direction of induced current, in the loop as shown in the figure? **(IIT-JEE 1979)**



Self Induction, Self Inductance, Self Induced Emf & Magnetic Energy Density

Single Correct

38. Two circular coils can be arranged in any of the three situations shown in the figure. Their mutual inductance will be **(IIT-JEE 2001)**



(A) (B) (C)

(a) maximum in situation (A).

(b) maximum in situation (B).

(c) maximum in situation (C)

(d) the same in all situations

@TAKE_CBSE X @RACEDUNET

39. A small square loop of wire of side l is placed inside a large square loop of wire of side $L(L >> l)$. The loops are coplanar and their centres coincide. The mutual inductance of the system is proportional to **(IIT-JEE 1998)**

(a) l/L (b) l^2/L

(c) L/l (d) L^2/l

Multiple Correct

40. Two different coils have self-inductances $L_1 = 8mH$ and $L_2 = 2mH$. The current in one coil is increased at a constant rate. The current in the second coil is also increased at the same constant rate. At a certain instant of time, the power given to the two coils is the same. At that time, the current, the induced voltage and the energy stored in the first coil are i_1, V_1 and W_1 respectively. Corresponding values for the second coil at the same instant are $i_2 V_2$ and W_2 respectively. Then **(IIT-JEE 1994)**

(a) $\frac{i_1}{i_2} = \frac{1}{4}$ (b) $\frac{i_1}{i_2} = 4$

(c) $\frac{W_1}{W_2} = \frac{1}{4}$ (d) $\frac{V_1}{V_2} = 4$

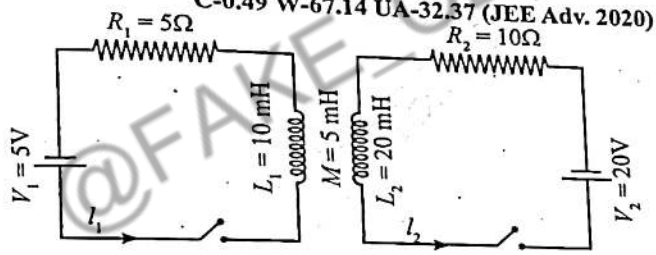
Fill in the Blanks

41. A uniformly wound solenoidal coil of self-inductance 1.8×10^{-4} H and resistance 6Ω is broken up into two identical coils. These identical coils are then connected in parallel across a $15V$ battery of negligible resistance. The time constant for the current in the circuit is .....s and the steady state current through the battery is ... A. **(IIT-JEE 1989)**

Numerical Types/Integer Types

42. The inductors of two LR circuits are placed next to each other, as shown in the figure. The values of the self-inductance of the inductors, resistances, mutual-inductance and applied voltages are specified in the given circuit. After both the switches are closed simultaneously, the total work done by the batteries against the induced EMF in the inductors by the time the currents reach their steady state values is _____ mJ.

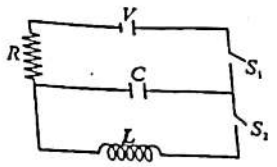
C-0.49 W-67.14 UA-32.37 (JEE Adv. 2020)



Circuit Containing Inductance, Resistance & Battery, Growth

Single Correct

43. The capacitor of capacitance C can be charged (with the help of a resistance R) by a voltage source V, by closing switch S_1 while keeping switch S_2 open. The capacitor can be connected in series with an inductor L by closing switch S_2 and opening S_1. **(IIT-JEE 2006)**



Initially, the capacitor was uncharged. Now, switch S_1 is closed and S_2 is kept open. If time constant of this circuit is τ, then

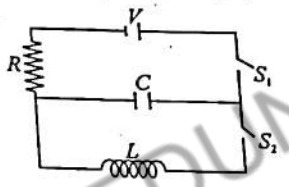
(a) after time interval τ, charge on the capacitor is

(b) after time interval 2τ, charge on the capacitor is $CV(1-e^{-2})$

(c) the work done by the voltage source will be half of the heat dissipated when the capacitor is fully charged

(d) after time interval 2τ, charge on the capacitor is $CV(1 - e^{-1})$.

44. The capacitor of capacitance C can be charged (with the help of a resistance R) by a voltage source V, by closing switch S_1 while keeping switch S_2 open. The capacitor can be connected in series with an inductor L by closing switch S_2 and opening S_1. **(IIT-JEE 2006)**



If the total charge stored in the LC circuit is Q_0, then for $t \geq 0$

(a) the charge on the capacitor is $Q = Q_0 \cos\left(\frac{\pi}{2} + \frac{t}{\sqrt{LC}}\right)$

(b) the charge on the capacitor is $Q = Q_0 \cos\left(\frac{\pi}{2} - \frac{t}{\sqrt{LC}}\right)$

(c) the charge on the capacitor is $Q = -LC\frac{d^2Q}{dt^2}$

(d) the charge on the capacitor is $Q = -\frac{1}{\sqrt{LC}}\frac{d^2Q}{dt^2}$

45. A coil of wire having finite inductance and resistance has a conducting ring placed co-axially within it. The coil is connected to a battery at time $t = 0$ s that a time dependent current $I_1(t)$ starts flowing through the coil. If $I_2(t)$ is the current induced in the ring and $B(t)$ is the magnetic field at the axis of the coil due to $I_1(t)$, then as a function of time $(t > 0)$, the product $I_2(t)\, B(t)$ **(IIT-JEE 2000)**

(a) increases with time (b) decreases with time

(c) does not vary with time (d) passes through a maximum

46. A coil of inductance $8.4mH$ and resistance 6Ω is connected to a $12V$ battery. The current in the coil is $1A$ at approximately the time **(IIT-JEE 1998)**

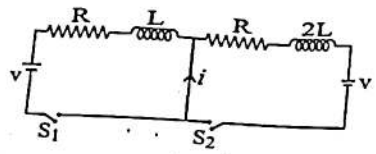
(a) $500s$ (b) $20s$ (c) $35ms$ (d) $1ms$

Multiple Correct

47. In the figure below, the switches S_1 and S_2 are closed simultaneously at $t = 0$ and a current starts to flow in the circuit. Both the batteries have the same magnitude of the electromotive force (emf) and the polarities are as indicated in the figure. Ignore mutual inductance between the inductors. The current I in the middle wire reaches its maximum magnitude I_{max} at time $t = \tau$. Which of the following statements is/are true?

C-11.2 W-32.31 UA-50.36 PC-6.14 (JEE Adv. 2018)

@FAKE_CBSE @RAJ_EDUNET



(a) $I_{max} = \frac{V}{2R}$ (b) $I_{max} = \frac{V}{4R}$ (c) $\tau = \frac{L}{R} ln2$ (d) $\tau = \frac{2L}{R} ln2$

Fill in the Blanks

Question Stem for Question Nos. 48 and 49

In a circuit, a metal filament lamp is connected in series with a capacitor of capacitance C μF across a 200 V, 50 Hz supply. The power consumed by the lamp is 500 W while the voltage drop across it is 100 V. Assume that there is no inductive load in the circuit. Take *rms* values of the voltages. The magnitude of the phase angle (in degrees) between the current and the supply voltage is φ. Assume, $\pi\sqrt{3} \approx 5$. **(JEE Adv. 2021)**

48. The value of C is ____. **C-8.02 W-68.84 UA-23.14**

49. The value of φ is ____. **C-12.46 W-63.77 UA-23.77**

Comprehension Based/Passage Based

A point charge Q is moving in a circular orbit of radius R in the x-y plane with an angular velocity ω. This can be considered as equivalent to a loop carrying a steady current $\frac{Q\omega}{2\pi}$. A uniform magnetic field along the positive z-axis is now switched on, which increases at a constant rate from 0 to B in one second. Assume that the radius of the orbit remains constant. The applications of the magnetic field induces an emf in the orbit. The induced emf is defined as the work done by an induced electric field in moving a unit positive charge around a closed loop. It is known that, for an orbiting charge, the magnetic dipole moment is proportional to the angular momentum with a proportionality constant γ. **(JEE Adv. 2013)**

50. The magnitude of the induced electric field in the orbit at any instant of time during the time interval of the magnetic field change is **C-31.15 W-19.15 UA-49.7**

(a) $\frac{BR}{4}$ (b) $\frac{BR}{2}$ (c) BR (d) $2BR$

51. The change in the magnetic dipole moment associated with the orbit, at the end of the time interval of the magnetic field change, is **C-14 W-24.37 UA-61.63**

(a) γBQR^2 (b) $-\gamma\frac{BQR^2}{2}$

(c) $\gamma\frac{BQR^2}{2}$ (d) γBQR^2

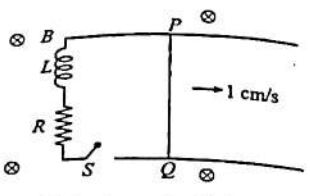
Numerical Types/Integer Types

52. A 10 cm long perfectly conducting wire PQ is moving, with a velocity 1cm/s on a pair of horizontal rails of zero resistance. One side of the rails is connected to an inductor $L = 1$ mH and a resistance $R = 1\Omega$ as shown in figure. The horizontal rails, L and R lie in the same plane with a uniform magnetic field $B = 1$ T perpendicular to the plane. If the key S is closed at certain instant, the current in the circuit after 1 millisecond is $x \times 10^{-3}$ A, where the value of x is_____.

[Assume the velocity of wire PQ remains constant (1 cm/s) after key S is closed.

Given: $e^{-1} = 0.37$, where e is base of the natural logarithm]

C-18.19 W-63.26 UA-18.55 (JEE Adv. 2019)

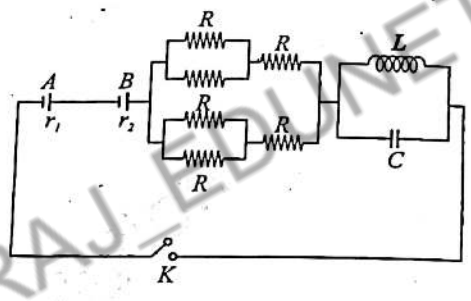


53. Two inductors L_1 (inductance $1mH$, internal resistance 3Ω) and L_2 (inductance $2mH$, internal resistance 12Ω), and a resistor R (resistance 12Ω) are all connected in parallel across a 5V battery. The circuit is switched on at time $t = 0$. The ratio of the maximum to the minimum current (I_{max} / I_{min}) drawn from the battery is **(JEE Adv. 2016)**

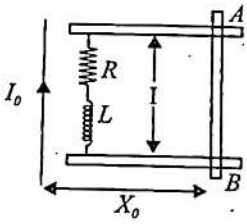
54. A solenoid has an inductance of $10H$ and a resistance of 2Ω. It is connected to a $10V$ battery. How long will it take for the magnetic energy to reach 1/4 of its maximum value ? **(IIT-JEE 1996)**

Subjective

55. In the circuit shown A and B are two cells of same emf E but different internal resistances r_1 and r_2 ($r_1 > r_2$) respectively. Find the value of R such that the potential difference across the terminals of cell A is zero, a long time after the key K is closed. **(IIT-JEE 2004)**



56. A metal bar AB can slide on two parallel thick metallic rails separated by a distance l. A resistance R and an inductance L are connected to the rails as shown in the figure. A long straight wire, carrying a constant current I_0 is placed in the plane of the rails as shown. The bar AB is held at rest at a distance x_0 from the long wire. At $t = 0$, it made to slide on the rails away from the wire. Answer the following questions. **(IIT-JEE 2002)**



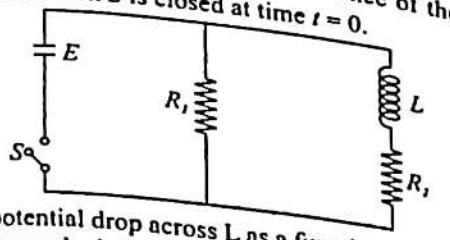
(a) Find a relation among $i, \frac{di}{dt}$ and $\frac{d\phi}{dt}$, where i is the current in the circuit and ϕ is the flux of the magnetic field due to the long wire through the circuit.

(b) It is observed that at time $t = T$, the metal bar AB is at a distance of $2x_0$ from the long wire and the resistance R carries a current i_1. Obtain an expression for the net charge that has flown through resistance R from $t = 0$ to $t = T$.

(c) The bar is suddenly stopped at time T. The current through resistance R is found to be $i_1/4$ at time $2T$. Find the value of L/R in terms of the other given quantities.

@FAKE_CBSE_X@RAJ_EDUNET

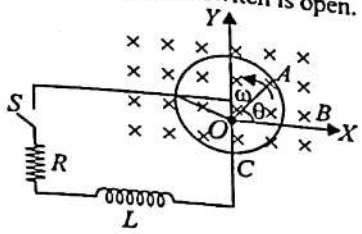
57. An inductor of inductance $L = 400mH$ and resistors of resistances $R_1 = 2\Omega$ and $R_2 = 2\Omega$ are connected to a battery of emf $E = 12V$ as shown in the figure. The internal resistance of the battery is negligible. The switch S is closed at time $t = 0$.



What is the potential drop across L as a function of time? After the steady state is reached, the switch is opened. What is the direction and the magnitude of current through R_1 as a function of time?

(IIT-JEE 2001)

58. A metal rod OA and mass and length r kept rotating with a constant angular speed ω in a vertical plane about horizontal axis at the end O. The free end A is arranged to slide without friction along a fixed conducting circular ring in the same plane as that of rotation. A uniform and constant magnetic induction B is applied perpendicular and into the plane of rotation as shown in figure. An inductor L and an external resistance R are connected through a switch S between the point O and a point C on the ring to form an electrical circuit. Neglect the resistance of the ring and the rod. Initially, the switch is open. **(IIT-JEE 1995)**



(a) What is the induced emf across the terminals of the switch?

(b) The switch S is closed at time $t = 0$.

(i) Obtain an expression for the current as a function of time.

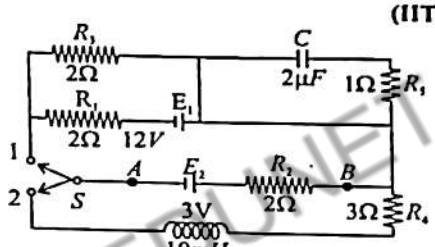
(ii) In the steady state, obtain the time dependence of the torque required to maintain the constant angular speed. Given that the rod OA was along the positive x-axis at $t = 0$

59. n infinitesimally small bar magnet of dipole moment M is pointing and moving with the speed v in the positive x-direction. A small closed circular conducting loop of radius a and negligible self-inductance lies in the y-z plane with its centre at $x = 0$, and its axis coinciding with the X-axis. Find the force opposing the motion of the magnet, if the resistance of the loop is R. Assume that the distance x of the magnet from the centre of the loop is much greater than a.

(IIT-JEE 1997)

60. A circuit containing a two-position switch S is shown in figure.

(IIT-JEE 1991)



(a) The switch S is in position 1. Find the potential difference $V_A - V_B$ and the rate of production of joule heat in R_1.

(b) If now the switch S is put in position 2 at $t = 0$. Find

(i) steady current in R_4 and

(ii) the time when current in R_4 is half the steady value. Also, calculate the energy stored in the inductor L at that time.

@FAKE_CBSE_X @RAJEEV_JHET

ANSWER KEY

JEE-Main

1. (c)	2. [2]	3. (d)	4. (b)	5. [2]
11. (a)	12. [12]	13. [2]	14. [250]	15. [60]
21. [3]	22. [32]	23. [216]	24. (3.24)	25. (c)
31. [1584]	32. [4]	33. (a)	34. [16]	35. (a)
41. (b)	42. (a)	43. [5]	44. (0)	45. (c)
51. [10]	52. (b)	53. [440]	54. (d)	55. [15]
61. (a)	62. (b)	63. (*)	64. (d)	65. [2]
71. (c)	72. (d)	73. [4]	74. [625]	75. (d)
81. (b)	82. (a)	83. (d)	84. (b)	85. (c)
91. [400]	92. [44]	93. [1]	94. [144]	95. (a)
101. [74]	102. (a)	103. (a)	104. [33.00]	105. (b)

6. (b)	7. (b)	8. (b)	9. [60]	10. [150]
16. (a)	17. (b)	18. (d)	19. (d)	20. [5]
26. (d)	27. (a)	28. [44]	29. [18]	30. [9]
36. (c)	37. (a)	38. (d)	39. (d)	40. (c)
46. (d)	47. [88]	48. [50]	49. [44]	50. [8]
56. (b)	57. (a)	58. [80]	59. (a)	60. (d)
66. [128]	67. (a)	68. [4]	69. (a)	70. [10]
76. (c)	77. (d)	78. [4]	79. (d)	80. [10]
86. (b)	87. [25]	88. [30]	89. [3]	90. (c)
96. (b)	97. (a)	98. (d)	99. [3]	100. (a)
106. (a)	107. [0.63]	108. (*)		

JEE-Advanced

1. (c)	2. (b)	3. (b, c, d)	5. (d)	6. (c)
14. [4]	15. [0.02]	16. [1]	17. [False]	20. [15]
26. (b, d)	27. (d)	28. [False]	31. (d)	32. (b)
40. (a,c,d)	42. [55]	43. (b)	44. (c)	45. (d)
51. (b)	52. [0.63]	53. [8]	54. [3.5]	

7. (a)	8. (d)	9. (c)	12. (b)	13. (d)
21. (b)	22. (c)	23. (d)	24. (b,d)	25. (a,c)
33. (b)	34. (d)	35. [7]	38. (a)	39. (b)
46. (d)	47. (b, d)	48. [100]	49. [60]	50. (b)

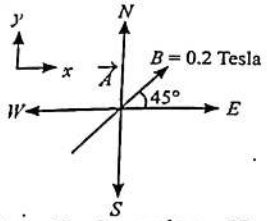
EXPLANATIONS

JEE-Main

1. (c) $\varepsilon = -\frac{\Delta\phi}{\Delta t}$

$= -\frac{0-(4\times(2.5\times2)\cos60°)}{10} = +1V$

2. [2]



Given side of square loop = 10 cm

Resistance = 0.7 ohm

$B = 0.20$ T

$\Delta t = 1$s

$\vec{A} - (0.1)^2\,\hat{j}$

$\vec{B} = \frac{0.2}{\sqrt{2}}\hat{i} + \frac{0.2}{\sqrt{2}}\hat{j}$

Magnitude of induced emf

$e = \frac{\Delta\phi}{\Delta t} = \frac{\vec{B}.\vec{A}-0}{1} = \sqrt{2}\times10^{-3}$ V

Therefore, $x = 2$

3. (d) Maxwell's equation

4. (b) EMF induced,

$\varepsilon = N\left(\frac{\Delta\phi}{t}\right)$

Magnetic flux, $\Delta\phi = (\Delta B)A$

$\Delta\phi = (\Delta B)A$

$= (2000)\pi(0.01)^2 = 0.2\pi$

$\varepsilon = N\left(\frac{\Delta\phi}{t}\right) \Rightarrow 22 = N\left(\frac{0.2\pi}{2}\right)$

$N = 70$

5. [2] Emf, $\varepsilon = -\left(\frac{d\phi}{dt}\right) = 10t - 36$

at t = 2, ε = 16 V

Current, $i = \frac{\varepsilon}{R} = \frac{16}{8} = 2$A

6. (b) Magnetic flux, $\phi = \vec{B}\cdot\vec{A}$

$= BA\cos\theta$

Most suitable ans is (b) [Otherwise *ABCD*]

7. (b) Using Faraday's Law of EMI,

$EMF = \frac{d\phi}{dt} = \frac{BA-0}{t}$

$A = \pi r^2 = \pi\left(\frac{0.1^2}{\pi}\right) = 0.01\,m^2$

and $B = 0.5\,T$

$\Rightarrow EMF = \frac{(0.5)(0.01)}{0.5} = 10mV$

8. (b) Length of each side of the loop, $\ell = 5$cm

and, $t = 1$ sec

$\therefore v = \frac{0.05}{1} = 0.05\,m/s$

$i = \frac{B\ell v}{R} = \frac{40\times0.05\times0.05}{10} = 0.01\,A$

$\therefore F = i\ell B = 40\times0.01\times0.05 = 0.02\,N$

$\therefore W = 0.02\times\ell = 0.02\times.05 = 1\times10^{-3}J$

9. [60]

$\therefore \Delta Q = \frac{2NBA}{R} = \frac{2\times100\times1.5\times24\times10^{-4}}{12}$

$= 6\times10^{-2}$ C = 60 mC

10. [150] $F = qVB$

$qE = qVB$

$\frac{\Delta V}{d} = VB$

$\Delta V = (v\,B)d$

$\Delta V = (2\times1/2)\,0.15$

$\Delta V = 150\,mV$

11. (a) We have, $\phi = (5t^3 + 4t^2 + 2t - 5)$

$V = \frac{-d\phi}{dt} = -(15t^2 + 8t + 2)$

at $t = 2$ sec, $V = -(15\times4 + 8\times2 + 2)$

$= 78$ V

$I = \frac{V}{R} = \frac{78}{5} = 15.6\,A$

12. [12] $\phi = \vec{B}\cdot\vec{A} = \left(3t^3\hat{j} + 3t^2\hat{k}\right)\cdot\left(\pi(1)^2\hat{k}\right)$

$\phi = 3t^2\pi$

$\varepsilon_{IND} = \left|\frac{d\phi}{dt}\right| = 6t\pi$

At, $t = 2$, $\varepsilon_{IND} = 12\pi$

The value of n is 12.

13. [2] $\phi = \frac{2}{3}(9 - t^2) = 0$

$\Rightarrow t = 3$ sec is the when flux becomes zero.

$emf = \frac{-d\phi}{dt} = \frac{4t}{3}$

$I = \frac{emf}{R} = \frac{\frac{4}{3}t}{8} = \frac{t}{6}$

Heat produced

$= \int I^2 R dt = \int_0^3 \frac{t^2}{36}\times8dt = 2J$

14. [250] $\phi = 8t^2 - 9t + 5$

$\text{emf} = -\frac{d\phi}{dt} = -(16t - 9)$

At $t = 0.25\,s$

$\text{emf} = -[(16\times0.25) - 9] = 5V$

$\text{Current} = \frac{\text{emf}}{\text{Resistance}} = \frac{5V}{20}$

$= \frac{1}{4}\text{ A} = \frac{1000}{4}\text{ mA} = 250\text{ mA}$

15. [60] $|E| = \frac{d\phi}{dt} = 20t + 20$ mV

$|i| = \frac{|\varepsilon|}{R} = 10t + 10$ mA

At $t = 5$

$|i| = 60$ mA

16. (a) According to the faraday's law of electromagnetic induction, $EMF = \frac{-d\phi}{dt}$

When magnet passes through the centre rogion of loop, no emf is induced. By using the Lenz's law, the polarity of emf will be negative while entering the loop.

17. (b) $I = I_0 t - I_0 t^2$

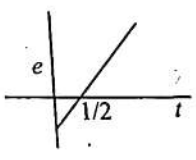
$\phi = BA$

$\phi = \mu_0 nIA$

$V_R = \frac{d\phi}{dt} = -\mu_0 nAI_0(1-2t)$

$V_R = 0$ at $t = \frac{1}{2}$ and I_R

$= \frac{V_R}{\text{Resistance of loop}}$



@FAKE_CBSE_X @RAJ_EDUNET

18. (d) $\varepsilon = \left|-\frac{d\varphi}{dt}\right| = \left|-\frac{AdB}{dt}\right|$

$= (16\times4-4\times2)\frac{(1000-500)}{5}\times10^{-4}\times10^{-4}$

$= 56\times\frac{500}{5}\times10^{-8} = 56\times10^{-6}V$

19. (d) Current direction reverses when magnet exits from solenoid and when magnet is completely inside, current is zero.

20. [5] $I = 5t^2 - 2t + 3$

$\frac{dI}{dt} = 10t - 2$

At $(t = 1\text{ sec})$ $\left(\frac{dI}{dt}\right) = 8$ A/s

$\phi = \left(\frac{\mu_0\times200\times I\times100}{2\times20}\right)\times\frac{\pi\times500}{100\times100}$

$\therefore e = \left|\frac{d\phi}{dt}\right| = \frac{\mu_0\times200\times100\times500\times\pi}{2\times20\times100\times100}\left(\frac{dI}{dt}\right)$

$\Rightarrow e = \left|\frac{d\phi}{dt}\right| = \left(\frac{8}{10}\right)m$ volt $= \frac{4}{5}$ m volt

$x = 5$

21. [3] Length of wire, l = 5 m velocity is 10 ms^{-1}

$B_H = 0.60\times10^{-4}$ Wb/m²

Induced emf $e = B_H vl$

$= 0.60\times10^{-4}\times10\times5 = 3\times10^{-3}$ V

22. [32]

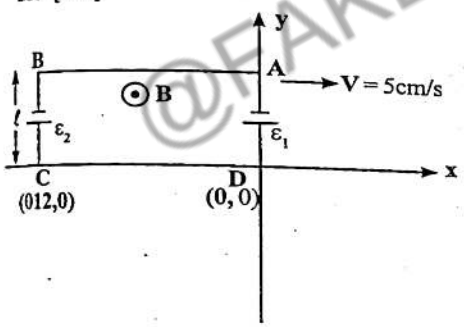
Given, $B_v = B\sin30 = \frac{1}{4}\times10^{-4}$

$\omega = 2\pi\times f = \frac{2\pi}{60}\times\frac{1200\text{rad}}{\text{s}} = 40\pi$ rad/s

As we know that, $\varepsilon = \frac{1}{2}B_v\omega\ell^2$

$= 32\pi\times10^{-5}$ V

23. [216]



Where, B_0 is the magnetic field at origin

Now, $\frac{dB}{dx} = -\frac{10^{-3}}{10^{-2}}$

$\Rightarrow \int_{B_0}^{B} dB = -\int_0^x 10^{-1}dx$

$\Rightarrow B - B_0 = -10^{-1}x$

$\Rightarrow B = \left(B_0 - \frac{x}{10}\right)$

Motional emf in AB and CD = 0

Motional emf in AD = $\varepsilon_1 = B_0\ell v$

Hence, Magnetic field on rod BC

$B = \left(B_0 - \frac{(-12\times10^{-2})}{10}\right)$

Motional emf in BC = ε_2

$= \left(B_0 + \frac{12\times10^{-2}}{10}\right)\ell\times v$

$\varepsilon_{eq} = \varepsilon_2 - \varepsilon_1 = 300\times10^{-7}$ V

For time variation magnetic field,

$(\varepsilon_{eq})' = A\frac{dB}{dt} = 60\times10^{-7}$ V

$(\varepsilon_{eq})\text{net} = \varepsilon_{eq} + (\varepsilon_{eq})' = 360\times10^{-7}$ V

Power $= \frac{(\varepsilon_{eq})^2_{net}}{R} = 216\times10^{-9}$ W

24. (3.24)

EMF induced in the loop,

$\in = NB\ell v$

current in the square loop,

$i = \frac{\in}{R} = \frac{NB\ell v}{R}$

$F = N(i\ell B) = \frac{N^2B^2\ell^2v}{R}$

work done in pulling the loop out of the field,

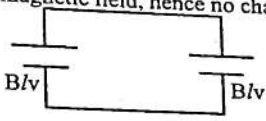
$W = F\times\ell = \frac{N^2B^2\ell^3}{R}\left(\frac{\ell}{t}\right)$

$A = \ell^2$

$W = \frac{(10\times10)(0.5)^2\times(3.6\times10^{-3})^2}{100\times1}$

$W = 3.24\times10^{-6}$ J

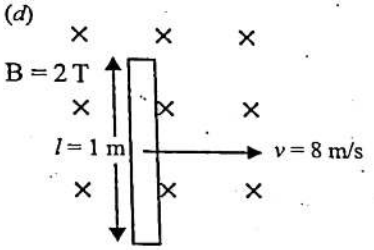
25. (c) At t =10 sec complete loop is in magnetic field, hence no change in flux



Induced emf in the loop, $e = \frac{d\phi}{dt} = 0$

Thus, $e = 0$ for complete loop.

26. (d)



Induced emf across the ends of the rod $= B\ell v$

$= 2\times8\times1 = 16$ V

27. (a) Given length of rod , l = 10 cm = 0.10m

Magnetic field, $B = 0.4\ T$

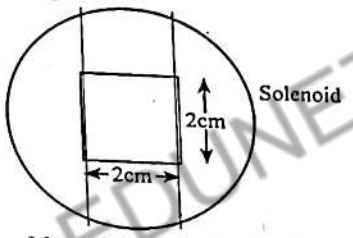
c.m.f. $\varepsilon = 0.08V$

Induced emf $\varepsilon = Blv$

$\therefore v = \frac{\varepsilon}{Bl}$

$\Rightarrow v = \left(\frac{0.08}{0.4\times0.10}\right) = 2\ m/s$

28. [44]



Magnetic field due to solenoid = $\mu_0 nI$

Flux through square loop = $\mu_0 nI\times A$

Induced emf = $\mu_0 nA\times\frac{dI}{dt} = \mu_0 nA\times I_0\omega$

cos ωt

$|\text{emf}| = \mu_0 nA\times I_0\omega$

$= (4\pi\times10^{-7})\times\left(\frac{50}{10^{-2}}\right)\times(4\times10^{-4})$

$\times (2.5)\times(700)$

$= 44\times10^{-4}$ V

$\therefore x = 44$

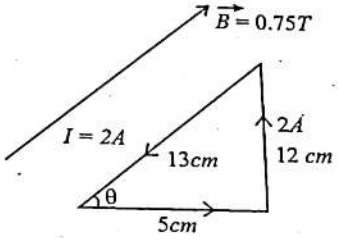
29. [18] Force needed to move the rod is

$F = i\ell B$

$= \left(\frac{vB\ell}{R}\right)\ell B = \frac{vB^2\ell^2}{R} = \frac{4}{5}\times\left(\frac{15}{100}\right)^2\times1^2$

$F = \frac{4}{5}\times\frac{225}{10^4} = \frac{180}{10^4} = 0.018N = 18\times10^{-3}$N

30. [9]



Force on the 5 *cm* side of the triangle is

$|\vec{F}| = ILB\sin\theta$

$= (2)(5\times10^{-2})\times\frac{3}{4}\times\frac{12}{13} = \frac{9}{130}N$

$\Rightarrow x = 9$

@FAKE_CBSE_X @RAJ_EDUNET

31. [1584] *Emf* induced in a rectangular coil is

$\varepsilon = NAB\omega\sin\omega t$

For *emf* to be maximum $\sin\omega t = 1$

$\Rightarrow \varepsilon_{max} = NBA\omega$

$= 100\times14\times10^{-2}\times3\times\frac{360\times2\pi}{60} = 1584V$

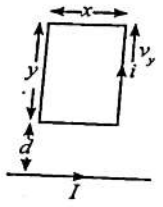
32. [4] Length of loop $(y) = 4cm$

Width of loop $(x) = 2cm$

Resistance of loop $(R) = 0.1\ \Omega$

Induced emf, $\varepsilon = (B_1 - B_2)xv_y$

Induce current



Induce current

$$i = \frac{\varepsilon}{R} = \frac{\mu_0 I}{2\pi R}\left(\frac{1}{d} - \frac{1}{d+y}\right)xv_y$$

$$\Rightarrow 10\times10^{-6} = \frac{4\pi\times10^{-7}\times10}{2\pi\times0.1}\left[\frac{1}{4} - \frac{1}{8}\right]\times2\cdot v_y$$

$\therefore V_y = 2$

$$\tan\theta = \frac{v_y}{v_x} = \frac{1}{\sqrt{3}}$$

$\Rightarrow v_x = v_x\sqrt{3}$

$\therefore v_x = 2\sqrt{3}$

Value of velocity,

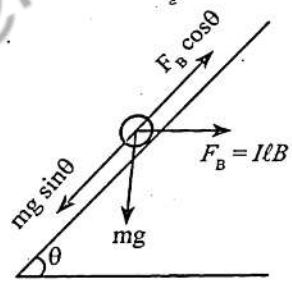
$\therefore v = \sqrt{v_x^2 + v_y^2}$

$= \sqrt{(2\sqrt{3})^2 + (2)^2} = \sqrt{16} = 4$ m/s

33. (*a*) Let length $= \ell$

For equilibrium of rod:

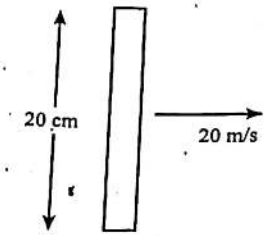
$mg\sin45° = F_B\cos45°$



$\Rightarrow (0.45\ell)\,g = I\ell B$

So, $I = \frac{0.45\times10}{0.15} = 30A$

34. [16] $B_H = 4\times10^{-3}$ T, $B = B_H\tan45° = 4\times10^{-3}$ T



$\theta \to 45°$

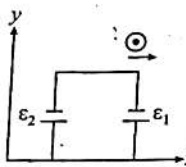
$B_v = B_H$

$\varepsilon = (\vec{V}\times\vec{B})\cdot\vec{l} = BVl$

$\left(\left(4\times10^{-3}\right)(200)\right)\frac{20}{100}$

$16\times10^{-3}\,V = 16$ mV

35. (*a*)



[As $\vec{V}\times\vec{B}$ is along the conductor length for two arms of the loop]

Assumed after some time, loop moved x distance.

$$\varepsilon_1 = \frac{B_0(x+d)}{a}v_0 d$$

$$\varepsilon_2 = \frac{B_0\times dv_0}{a}$$

$$\therefore \varepsilon_{net} = \varepsilon_1 - \varepsilon_2 = \frac{B_0 v_0 d^2}{a}$$

36. (*c*) The induce emf at $t = 1s$ i.e. at $x = 0m$ is,

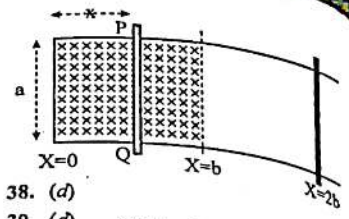
$E = B\,l\,v = B(2R)v$

$\Rightarrow E = 1\times1\times2\times1 = 2V$

37. (*a*) When arm PQ of a rectangular conductor is moving from $x = 0$ to $x = b$, the flux ($\phi = ax$) linked with loop increases and while moving from $x = b$ to $x = 2b$ and from $x = 2b$ to $x = b$, flux ($\phi = ab$) remains constant and then flux ($\phi = ax$) deceases to zero as it moves from $x = b$ to $x = 0$

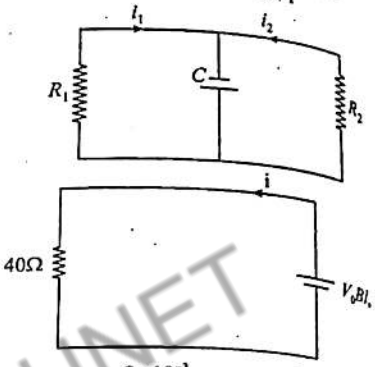
$e_{in} = -\frac{d\phi}{dt} = -a\frac{dx}{dt} = -av \Rightarrow$ Induced *emf*

$P = \frac{(e_{in})^2}{R}$



38. (*d*)

39. (*d*) $I = \frac{V_0 B\ell}{R} = \frac{V_0\times5\times20\times10^{-3}}{4+1}$



$V_0 = \frac{2\times10^{-3}}{20\times10^{-2}} = 1\times10^{-2}$ m/s

$V_0 = 1$cm/s

40. (*c*) $\varepsilon = Bv\ell$

$i = \frac{\varepsilon}{R}$

$i = \left(\frac{\mu_0 I}{2\pi r}v\ell\right)\frac{1}{R}$

41. (*b*) Since it is a balanced wheatstone bridge, its equivalent resistance $= \frac{4}{3}\Omega$

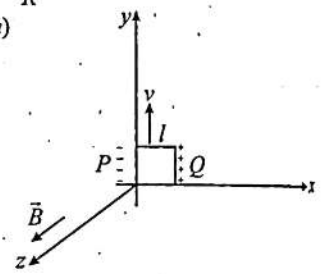
$\varepsilon = B\ell v = 5\times10^{-4}$ V

so total resistance

$R = \frac{4}{3} + 1.7 \approx 3\Omega$

$i = \frac{\varepsilon}{R} \approx 166\mu A \approx 170\mu A$

42. (*a*)



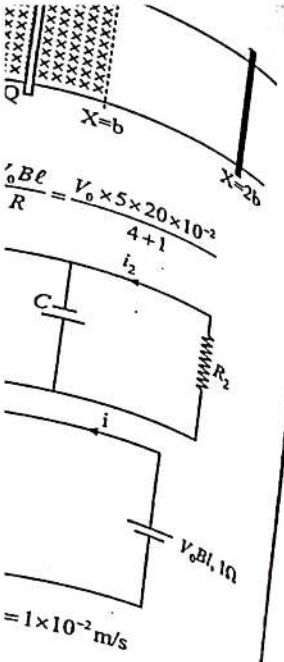
Motional emf induced across faces P and Q of cube is

$e = Bvl$

$= 0.1\times6\times0.02$

$= 12\times10^{-3}\,V = 12$ mV

@FAKE_CBSE XII_RAJ_EDUNET



balanced wheatstone
ent resistance $= \frac{4}{3}\Omega$
V

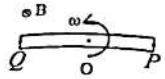
μA

x

cross faces P and

43. [5] $\phi = NAB\cos(\omega t)$
Induced emf
$\varepsilon = -\frac{d\phi}{dt}$ $NAB\omega\sin(\omega t)$
$\varepsilon_{max} = NAB\omega$
$= 200 \times 0.2 \times 0.01 \times \pi$
$= \frac{4\pi}{10} = \frac{2\pi}{5}$ volt

44. (0)

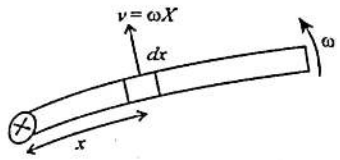


$V_0 - V_P = \frac{B\omega\ell^2}{2}$

$V_0 - V_Q = \frac{B\omega\ell^2}{2}$

$\therefore V_P = V_Q \therefore V_P - V_Q = 0$

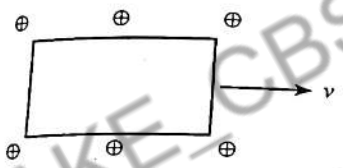
45. (c)



Emf included in the rod is
$\int d\varepsilon = \int B(\omega x)dx$

$\therefore \varepsilon = B\omega\int_0^L x dx = \frac{B\omega L^2}{2}$

46. (d)



$e = -\frac{d\phi}{dt} = -\frac{d}{dt}(BA_{cos\theta})$

A coil moving inside a uniform magnetic field with uniform or non-uniform speed doesn't change flux, so, no emf is induced.

47. [88] Here $\omega = 210$ *rpm*

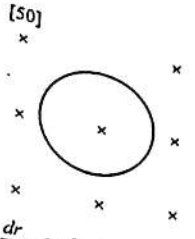
$= 210 \times \frac{2\pi}{60} rad/s \left(\because 1rpm = \frac{2\pi}{60} rad/s\right)$

$\Rightarrow \omega = 7\pi$ rad/s
$\ell = 0.2$ m
B = 0.2T

emf induced across the rod $= \frac{1}{2}B\omega\ell^2$

$e = \frac{1}{2} \times 0.2 \times 7\pi \times (0.2)^2 = 88$ mV

48. [50]



$\frac{dr}{dt} = 10^{-3} m/s$

Area of the loop $A = \pi r^2$
$\therefore \frac{dA}{dt} = 2\pi r\frac{dr}{dt}$

$\varepsilon = \left|\frac{-d\phi}{dt}\right| = \left|\frac{BdA}{dt}\right| = B.2\pi r\frac{dr}{dt}$
$= 0.4 \times 2 \times \pi \times 2 \times 10^{-2} \times 10^{-3} V$
$= 16\pi\mu V = 50.24\ \mu V$

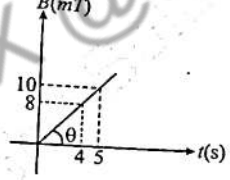
49. [44] $\omega = \frac{500 \times 2\pi}{60} = \frac{100\pi}{6} rad/s$

$\therefore E = NAB\omega\sin\omega t$

$= 600 \times 70 \times 10^{-4} \times 0.4 \times \frac{100\pi}{6} \times \frac{1}{2}$

$\Rightarrow E = 44\ V$

50. [8] Slope $m = \frac{Y_2 - Y_1}{x_2 - x_1} = \frac{10-8}{5-4} = 2$



$\varepsilon = \left|\frac{d\phi}{dt}\right| = \frac{d(BA)}{dt} = \frac{AdB}{dt}$

$A \times$ (Slope of $B - t$ curve)
$\varepsilon = 4 \times 2 = 8mVolt$

51. [10] Induced $emf = \frac{d}{dt}(BA)$,
where $A = \pi r^2$

$= 2B\pi r\frac{dr}{dt}$

$= 2 \times \pi \times 0.1 \times 0.8 \times 2 \times 10^{-2}$
$= 2\pi \times 1.6 = 10.06$ [round off $10.06 = 10$]

52. (b) Emf induced between the two end = $\frac{B_H\omega l^2}{2}$

$= \frac{0.2 \times 10^{-4} 5 \times 1}{2} = 0.5 \times 10^{-4}$

$= 50 \times 10^{-6}$ V 50 μV

53. [440] Given, $N = 1000$, $A = 1m^2$, $B = 0.07$T
$\omega = 1$ rev/sec $= 2\pi$ rad/sec
$\therefore V_{max} = NBA\omega$
$= 1000 \times 0.07 \times 1 \times 2\pi = 440$V

54. (d) $\therefore \omega = \frac{2\pi}{T} = \frac{\pi}{5}$

When $\omega t = \frac{\pi}{2}$

$\because \phi$ will be minimum.
$\therefore e$ will be maximum

$t = \frac{\frac{\pi}{2}}{\frac{\pi}{5}} = 2.5$sec

When $\omega t = \pi$

$\because \phi$ will have maximum

$\because e$ will be minimum.

$t = \frac{\pi}{\pi/5} = 5$sec.

55. [15] Magnetic flux, $\phi = \vec{B} \cdot \vec{A}$
$= BA\cos(\omega t)$

emf induced, $e = \frac{-d\phi}{dt} = AB\omega\sin(\omega t)$
Maximum value of emf $= AB\omega = \omega R^2 B\omega$

$3.14 \times 0.1 \times 0.1 \times 3 \times 10^{-5} \times \frac{\pi}{0.2}$
$= 15 \times 10^{-6} = 15\ \mu V$
Hence, the required integer is 15.

56. (b) When the magnet is moved, it creates a state where the plate moves through the magnetic flux, due to which an electromotive force is generated in the plate and eddy currents are induced. These currents are such that it opposes the relative motion ⇒ disc will rotate in the direction of rotation of magnet.
Note: This apparatus is called Arago's disk.

57. (a) Retarded or accelerated charge may produce time varying electric and magnetic fields. While an electric field varying linearly with time will not produce variable magnetic field because of the current become constant.

58. [80]

$\varepsilon = \left|\frac{d\phi}{dt}\right| = A\frac{dB}{dt} = \pi \times 1^2 \times \frac{4}{\pi} \times 10^{-3} \times \frac{1}{100}$
$= 4 \times 10^{-5}$ V
When magnetic field switched off, $B = 0$,

$\therefore \frac{4}{\pi} \times 10^{-3}\left(1 - \frac{t}{100}\right) = 0$

@FAKE_CBSE X @RAJ_EDUNET

$\Rightarrow t = 100$ second

Energy dissipated,

$$E = I^2Rt = \frac{\varepsilon^2}{R}t = \frac{(4\times10^{-5})^2}{2\times10^{-6}}\times100 = 80\text{mJ}$$

59. (*a*) Using faraday's law $\vec{B}$ should be outward and decreasing for anticlockwise induced current.

60. (*d*) Induced emF for rotating loop,

$\varepsilon_0 = BA\omega = B(\pi ab)\omega \quad [\because A = \pi ab]$

$\therefore$ Average power loss due to Joule's heating effect is

$$< P > = \frac{\varepsilon_0^2}{2R} = \frac{\pi^2a^2b^2B^2\omega^2}{2R}$$

61. (*a*) $|U_f - U_i| = \frac{1}{2}I\omega^2$

$$20\times4\times\frac{\sqrt{3}}{2} - 0 = \frac{1}{2}\times(0.8)\omega^2$$

$\Rightarrow \omega = 13.16$ rad/s

62. (*b*) Area of loop $= \frac{l^2}{16}$

$$\varepsilon = \frac{d\phi}{dt} = \left(\frac{dB}{dt}\right)\frac{l^2}{16}$$

$$I = \frac{\left(\frac{dB}{dt}\right)\frac{l^2}{16}\times\frac{\pi d^2}{4}}{\rho l}$$

$I = 0.61$ A

63. (*) In time varying magnetic field, charge flown through a loop is given as –

$$q_f = \frac{\Delta\phi}{R} = \frac{A.\Delta B}{R} = \frac{A}{R}\times(B_{10ms} - B_0)$$

$$\Rightarrow q_f = \frac{3.5\times10^{-3}}{10}\times\left[0.4\sin\left(\frac{\pi}{2}\right) - 0\right]$$

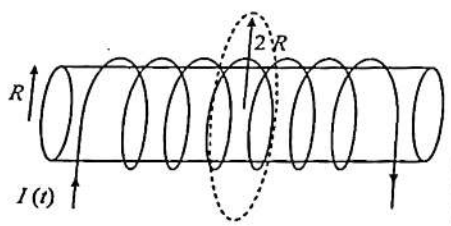
$$\Rightarrow q_f = 3.5\times10^{-4}\times0.4 \cong 0.14\times10^{-3}C.$$

64. (*d*) Current in solenoid $I(t) = kte^{-\alpha t}$

Flux through solenoid is $\phi(t) = B.A = (\mu_0 nl)\times\pi R^2$

$\rightarrow$ same flux will pass through coil of radius $2R$.

emf induced in outer coil is $e = -\frac{d\phi}{dt}$



$$\Rightarrow e = -\mu_0 n\pi R^2 k\left[e^{-\alpha t} + t(-\alpha e^{-\alpha t})\right]$$

$$\Rightarrow e = -Ce^{-\alpha t}(1-\alpha t)$$

Current induced in coil is $I_{coil} = \frac{e}{R_{coil}}$

$$\Rightarrow I_{coil} = \frac{-C}{R}e^{-\alpha t}(1-\alpha t)$$

at $t = 0 \rightarrow I_{coil} = -ve$ and non-zero

at $t = \infty \rightarrow I_{coil} \rightarrow 0$

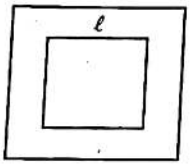
65. [2] $\phi = Mi = Mi_0\sin\omega t$

$$\text{EMF} = -M\frac{di}{dt} - 0.002\ (i_0\omega\cos\omega t)$$

$$\text{EMF}_{max} = i_0\omega\ (0.002) = (5)(50\pi)(0.002)$$

$$\text{EMF}_{max} = \frac{\pi}{2}\text{ V}$$

66. [128]



Flux lines linked for inner loop

$$\phi = B_{center}\cdot\ell^2$$

$$= 4\times\frac{\mu_0 i}{4\pi\frac{L}{2}}(\sin45 + \sin45)\ell^2$$

$$\phi = 2\sqrt{2}\frac{\mu_0 i}{\pi L}\ell^2$$

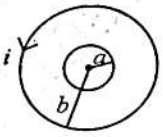
$$M = \frac{\phi}{i} = \frac{2\sqrt{2}\mu_0\ell^2}{\pi L} = 2\sqrt{2}\frac{\mu_0}{\pi}$$

$$= 2\sqrt{2}\frac{4\pi}{\pi}\times10^{-7} = \sqrt{128}\times10^{-7}H$$

$x = 128$

67. (*a*) Magnetic flux through the inner loop,

$\phi = BA = Mi$



$$\Rightarrow Mi = \frac{\mu_0 i}{2b}\pi a^2$$

$$\therefore M = \frac{\mu_0\pi a^2}{2b}$$

68. [4] The current in the inductor

$I = 3t + 8$

$\varepsilon = 12$ mV

$$|\varepsilon| = L\left|\frac{dI}{dt}\right|$$

$12 = L\times3$

$L = 4$ mH

69. (*a*) $(\text{Emf})_{induced} = -L\frac{di}{dt}$

$$\Rightarrow 0.1 = \frac{(L)[+2-(-2)]}{0.2}$$

(ignore –ve sign)

$$\Rightarrow L = \frac{0.1\times0.2}{4} = 5\text{mH}$$

70. [10]

Case-I:

$$i = \frac{20}{R} \Rightarrow R = 4\Omega$$

Case-II:

$$i = \frac{20}{Z} \Rightarrow 4 = \frac{20}{\sqrt{R^2 + X_L^2}}$$

$$\Rightarrow \sqrt{R^2 + X_L^2} = 5$$

$$\Rightarrow R^2 + X_L^2 = 25 \Rightarrow X_L = 3\Omega$$

$$\therefore L = \frac{3}{2\pi f} = \frac{1}{2\times50} = \frac{1000}{100}\text{mH}$$

$\Rightarrow L = 10$ mH

71. (*c*) $\phi = Mi$ ...(i)

and $\phi = (BA)$ ...(ii)

Magnetic field at point O due to the one side of the square loop $B = \frac{\mu_0}{4\pi}\frac{i\sqrt{2}}{\left(\frac{L}{2}\right)}$

$$\Rightarrow \phi = A\times B_{Total}$$

$$\Rightarrow \phi = \pi R^2\left(4\frac{\mu_0}{4\pi}\frac{i}{\left(\frac{L}{2}\right)}\sqrt{2}\right)$$

$$\Rightarrow M = \frac{2\sqrt{2}\mu_0 R^2}{L}$$

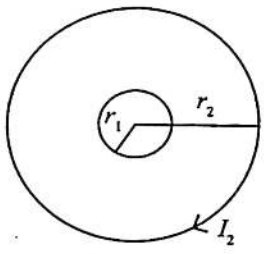
72. (*d*) Current in the cireuit, $I = \frac{12}{6} = 2A$

Induced $emf = -L\frac{dI}{dt}$

$$\Rightarrow 20 = -L\frac{(0-2)}{10^{-3}}$$

$\Rightarrow L = 10\ mH$

73. [4]



$\phi_{1,2} = MI_2$

$$N_2\vec{B}_2\cdot N_1\vec{A}_1 = MI_2 \Rightarrow M = \frac{N_1N_2\mu_0\pi r_1^2}{2r_2}$$

@FAKE_CBSE_X @RAJ_EDUNET

$(\text{Emf})_{\text{induced}} = -L\frac{di}{dt}$

$= \frac{(L)[+2-(-2)]}{0.2}$

–ve sign)

$\frac{0.1\times 0.2}{4} = 5\text{mH}$

$R = 4\Omega$

$I = \frac{20}{\sqrt{R^2+X_L^2}}$

$= 5$

$= 25 \Rightarrow X_L = 3\Omega$

$\frac{1}{2\times 50} = \frac{1000}{100}\text{mH}$

t point O due to the one ...(i) ...(ii)

: loop $B = \frac{\mu_0}{4\pi}\frac{i\sqrt{2}}{\left(\frac{L}{2}\right)}$

$\frac{i}{\frac{L}{2}}\sqrt{2}$

uit, $I = \frac{12}{6} = 2A$

$\frac{N_1N_2\mu_0\pi r_1^2}{2r_2}$

$N_1N_2\frac{\mu_0 I_2}{2r_2}\cdot\pi r_1^2 = MI_2$

$M = \frac{10\times 200\times 4\pi\times 10^{-7}\times\pi\times(0.01)^2}{2\times 1000\times 10^{-2}}$

$= 4\times 10^{-8}$

74. [625] At equilibrium (Steady state) inductor would act as a short circuit
∴ From ohm's law

$I = \frac{V}{R} = \frac{5}{2}A$

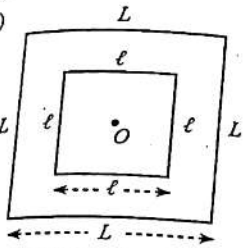
$E = \frac{1}{2}LI^2 = \frac{1}{2}\times 2\times\left(\frac{5}{2}\right)^2$

$= 6.25 = 625\times 10^{-2}\text{ T}$

75. (d) Current on both the inductor in opposite direction
Hence.

$L_{eq} = L_1 + L_2 - 2M$

76. (c)



Assuming current i in outer loop magnetic field at centre, flux through the smaller area

$\phi = 4\times\frac{\mu_0}{4\pi}\frac{i}{L/2}\times\left[\sin 45^\circ + \sin 45^\circ\right)\times A$

$= \frac{2\sqrt{2}\mu_0 i}{\pi L}\ell^2$

comparing with, $\phi = Mi$

$M = \frac{2\sqrt{2}\mu_0\ell^2}{\pi L}$

77. (d)

$P = \frac{E^2}{R} = \frac{\left(\frac{NAdB}{dt}\right)^2\times A_C}{\rho\ell}$

$P' = \frac{\left(\frac{NA}{2}\frac{dB}{dt}\right)^2\times 4A_C}{\frac{\rho\ell}{2}}$

$\therefore \frac{P'}{P} = 2 \Rightarrow P' = 2P$

78. [4] $I = 2\sin\left(t^2\right) \Rightarrow dI = 4t\cos\left(t^2\right)dt$

If $I = 0 \Rightarrow t = 0$ and For $I = 2$,

$\therefore t = \sqrt{\frac{\pi}{2}}$

$E = \int LIdI$

$= \int 2\times 2\sin\left(t^2\right)\times 4t\cos\left(t^2\right)dt$

$= 8\int_0^{\sqrt{\pi/2}} t\sin\left(2t^2\right)dt$

$= 2\left[-\cos\left(2t^2\right)\right]_0^{\sqrt{\pi/2}}$

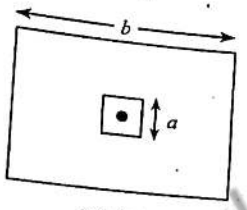
$= 2[-\cos\pi + \cos 0] = 4\text{J}$

79. (d) Here, magnetic field,

$B = \frac{\mu_0 I}{4\pi\frac{b}{2}}\times 2\sin 45^\circ\times 4$

$\phi = 2\sqrt{2}\frac{\mu_0 I}{\pi b}a^2$

$M = \frac{\phi}{I} = \frac{\mu_0}{4\pi}8\sqrt{2}\frac{a^2}{b}$



80. [10] $100 = \frac{L(0.25)}{0.025}\times 10^3$

$\therefore L = 100\times 10^{-4}\text{ H} = 10\text{ mH}$

81. (b) For mutual induction

$\phi = MI_p \Rightarrow M = \frac{\phi_q}{I_p} = \frac{10^{-3}}{3}$

$\phi_p = MI_q = \frac{10^{-3}}{3}\times 2 = 6.67\times 10^{-4}\text{ Wb}$

82. (a) $\phi = \text{NBA} = \text{LI}$
$N\mu_0 n l\pi R^2 = \text{LI}$

$\Rightarrow L = \frac{N^2\mu_0\pi R^2}{\ell}$ [Where; $N = nl$]

As, N and R are constant.

So, Self inductance (L) $\propto \frac{1}{\text{Length}}$

83. (d) Mutual inductance between coils is

$M = \mu_0 n_1 n_2\pi r_1^2 l$ ...(i)

Self inductance of inner coil is

$L = \mu_0 n_1^2\pi r_1^2 l$ ...(ii)

Using equation (i) and (ii),

$\Rightarrow \frac{M}{L} = \frac{n_2}{n_1}$

84. (b) $\because L = \frac{di}{dt} = 25$

$L\left(\frac{15}{1}\right) = 25 \Rightarrow L = \frac{5}{3}$

$\therefore \Delta U = \frac{1}{2}L\left(I_f^2 - I_{f1}^2\right) = \frac{1}{2}\times\frac{5}{3}\times(25^2 - 10^2)$

$= 437.5\text{ J}$

85. (c) Self inductance of a solenoid is given as

$L = \mu_0 n^2 Al\left(n = \frac{N}{l}\right)$

If sides of frame are made 3 times $\Rightarrow A \rightarrow 9A$

As frame sides are now 3 times so using same wire keeping same 'n'.

length of solenoid becomes $\frac{l}{3}$.

$\Rightarrow$ New self inductance will be $L' = \mu_0 n^2(9A)\frac{l}{3} = 3\text{ L}$

86. (b) Given C = 100 μF, V = 12V
$L = 6.4$ mH
By energy conservation

$\frac{1}{2}CV^2 = \frac{1}{2}LI_{max}^2$

$I_{max} = \sqrt{\frac{C}{L}}V$

$= \sqrt{\frac{100+10^{-6}}{6.4\times 10^{-3}}}\times 12 = \frac{12}{8} = \frac{3}{2} = 1.5\text{ A}$

The maximum current in the circuit would be 1.5 A.

87. [25]

$E = \frac{1}{2}LI^2 \Rightarrow \frac{dE}{dt} = \frac{1}{2}\times 2LI\frac{dI}{dt}$

Rate of energy storing $= LI\frac{dI}{dt}$

For $R-L$ circuit

$I = \frac{E}{R}\left(1 - e^{-\frac{Rt}{L}}\right)$

So $\frac{dI}{dt} = \frac{E}{L}e^{-\frac{Rt}{L}}$

$\frac{dE}{dt} = \frac{E^2}{R}\left(1 - e^{-\frac{Rt}{L}}\right)\left(e^{-\frac{Rt}{L}}\right)$

Time at which rate of power storing will be max,

$t = \frac{L}{R\ln 2}$

So, $\frac{dE}{dt} = \frac{E^2}{R}\left(1 - \frac{1}{2}\right)\times\frac{1}{2}$

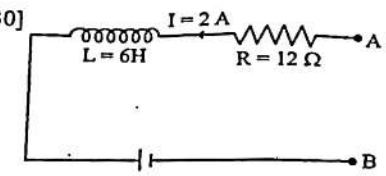
$\Rightarrow \frac{E^2}{4R} = \frac{E^2}{100} = \frac{E^2}{2\times 50}$

$a = 2, b = 50$

So, $\frac{b}{a} = 25$

@FAKE_CBSE X @RAJ_EDUNET

88. [30]



$$\frac{dI}{dt} = -I\frac{A}{sec}$$

$$V_A - IR - L\frac{dI}{dt} - 12 = V_B$$

$$V_A - 2\times12 - 6(-1) - 12 = V_B$$

$$V_A - V_B = 36 - 6 = 30 \text{ volt}$$

89. [3] For a dc circuit After long time an inductor behaves as a zero resistance path. So current through the cell,

$$I = \frac{12}{R/3} = 3A \{\because R = 12\Omega\}$$

90. (c) As, $i = i_0 e^{-t/\tau}$. $\Rightarrow \frac{i_0}{2} = i_0 e^{-t/\tau}$

$\Rightarrow -\ell n2 = -t/\tau$

$\Rightarrow t = \frac{L}{R}\ell n2. = \frac{1}{100}\ell n2 \doteq 7$ ms

at $t = 15$ms

$$i = \frac{6}{100}\left(e^{\frac{15}{1/100}}\right) = 0.06\times0.75 = 0.045A$$

$$\text{So, } U = \frac{1}{2}Li^2 = \frac{1}{2}\times1\times(45\times10^{-3})^2 = 1\text{mJ}$$

91. [400] $<\varepsilon> = \frac{\int \varepsilon dt}{\int dt} = \frac{\int (Ldi/dt)dt}{\int dt} = \frac{L\int di}{\int dt}$

$$<\varepsilon> = \frac{L\Delta i}{\Delta i}$$

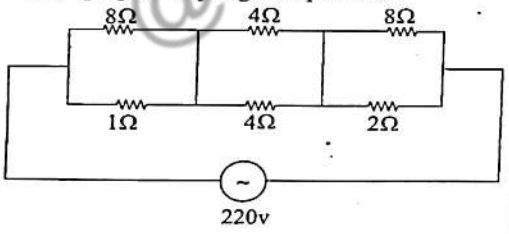
$$i_0 = \frac{V}{R} = \frac{20}{10} = 2\text{A, if } i = 0\text{A}$$

$T = 100\mu s, L = 20$mH

$$<\varepsilon> = \frac{20\times10^{-3}\times(2-0)}{100\times10^{-6}} = \frac{2\times10^3}{5}$$

$<\varepsilon> = 400$ V

92. [44] At very high frequencies



$X_C \to 0, X_L \to \infty$

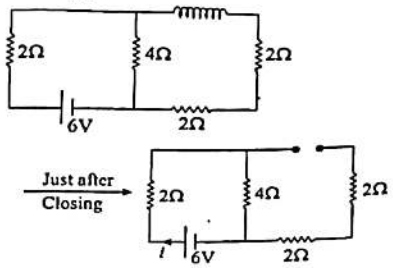
Thus, equivalent circuit

$$Z = 1 + \frac{4\times4}{4+4} + 2 = 5\Omega$$

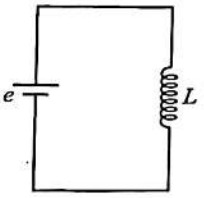
From ohm's law,

$$I = \frac{220}{5} = 44A$$

93. [1] $i = \frac{V_{net}}{R_{net}} = \frac{6}{6} = 1A$



94. [144]



$$\varepsilon = \frac{LdI}{dt}$$

$3\int_0^4 tdt = 2\int_0^I dI$

$\frac{3}{2}\times16 = 2I$

$I = 12$

$$V = \frac{1}{2}LI^2$$

$$= \frac{1}{2}\times2(12)^2 = 144\text{ J}$$

95. (a) We have given, R = 2Ω, L = 2 mH, E = 9 V

Under steady state inductor behaves like a short circuit

$$i = \frac{E}{2R} = \frac{9V}{4\Omega} = 2.25A$$

Just after the switch S is closed, the inductor acts as open circuit.

96. (b) Formula of Magnetic field energy

$$U_B = \frac{1}{2}LI^2 \quad \ldots (i)$$

Formula of energy dissipated, $P = I^2R$

$640 = (8)^2 R \Rightarrow R = 10\Omega$

From (i) $64 = \frac{1}{2}\times L\times(8)^2 \Rightarrow L = 2H$

Therefore, time constant

$$\tau = \frac{L}{R} = \frac{2}{10} = 0.2 \text{ seconds.}$$

97. (a) A solenoid is a cylindrical coil of wire. It makes a generally uniform attractive field in its inside, of solidarity.

$B = \mu ni$

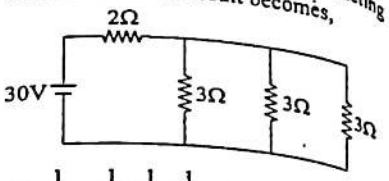
or $B = \mu_r\mu_0 ni$

$B = 500\times4\pi\times10^{-7}\times10^3\times5$

$B = \pi\times10^{-3}\times10^3$

$B = \pi T$

98. (d) Here inductor behave as a conducting wire so resultant circuit becomes,



$$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$$

$R_{eq} = 1\Omega$

Thus, current $I = \frac{30}{3} = 10$A

99. [3] When T_1 and T_2 are connected, then the steady state current in the inductor

$$I = \frac{6}{6} = 1\text{ A}$$

When T_1 and T_3 are connected then current through inductor remains same. So potential difference across 3 Ω

$V = Ir = 1\times3 = 3$ volt

100. (a) Magnetic energy, $U = \frac{1}{2}LI_0^2$

Given: $U = 25\%$ of U_0

$$\Rightarrow \frac{1}{2}LI^2 = \frac{1}{4}\times\frac{1}{2}LI_0^2.$$

$$\Rightarrow I^2 = \frac{I_0^2}{4} \Rightarrow I = \frac{I_0}{2}$$

$$\therefore I = I_0\left(1 - e^{-t/T}\right)$$

$$\Rightarrow \frac{I_0}{2} = I_0\left(1 - e^{-t/\tau}\right)$$

$$\Rightarrow \frac{1}{2} = e^{-t/\tau}$$

$$\Rightarrow e^{t/\tau} = 2$$

$$\Rightarrow t = \tau\ln 2$$

$$\Rightarrow t = \frac{L}{R}\ln 2$$

101. [74] Current in the circuit $I = I_0 e^{-t/\tau}$

where, $T = \frac{L}{R} = \frac{10\times10^{-3}}{10\times10^3} = 1\times10^{-6}$

Max. current in the circuit,

$$I_0 = \frac{V}{R} = \frac{20}{10\times10^3} = 2\times10^{-3}\text{A}$$

Therefore, $I = 2\times10^{-3}e^{\frac{1\times10^{-6}}{1\times10^{-6}}}$

$= 2\times10^{-3}\,e^{-1} = 2e^{-1}$mA $= 2\times0.37$ mA

$= \frac{74}{100}$mA

@FAKE_CBSE_X @RAJ_EDUNET

102. (a) $i=\frac{V}{r}\left(1-e^{-Rt/L}\right)=4\left(1-e^{-5000t}\right)$

At $t=\infty$

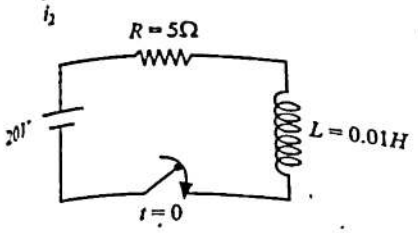
$i_1=4A$

At $t=40s$

$i_2=4\left(1-e^{-2000}\right)$

$=4\left[1-\frac{1}{\left(e^2\right)^{10000}}\right]=4\left[1-\frac{1}{(7.389)^{10000}}\right]$

$\frac{i_1}{i_2}$ is slightly greater than 1



103. (a) $q=\int_0^{T_C} i\,dt$

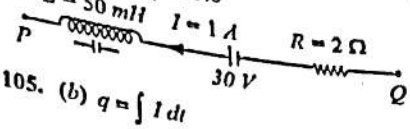
$=\frac{\varepsilon}{R}\left[t-\frac{e^{-t/T_C}}{\frac{-1}{T_C}}\right]_0^{T_C}$; $=\frac{\varepsilon}{R}\left[T_C+T_Ce^{-1}-T_C\right]$

$=\frac{\varepsilon}{R}\times\frac{1}{e}\times\frac{L}{R}$; $=\frac{\varepsilon L}{R^2e}$

104. (33.00)

$V_Q-2\times1+30+(50\times10^{-3})\times10^3=V_P$

$\Rightarrow V_P-V_Q=33.0$



105. (b) $q=\int I\,dt$

$q=\int_0^{L/R}\frac{E}{R}\left[1-e^{\frac{-Rt}{L}}\right]dt \Rightarrow q=\frac{EL}{R^2}\frac{1}{e}$

$\Rightarrow q=\frac{EL}{2.7R^2}$

106. (a) Self inductance of the coil $L=10\times10^{-3}\,H$ and resistance $r_1=0.1\,\Omega$

$i=\varepsilon\{1-e^{-t/2}\}$

$i_{saturation}=\varepsilon$

$80\%\ i_{saturation}=0.8\,\varepsilon$

$0.8\,\varepsilon=\varepsilon\{1-e^{-t/2}\}$

$0.8=1-e^{-t/2}$; $e^{-t/2}=0.2$

$e^{t/2}=5$

$t=L\ln 5=10\times10^{-3}\times1.6=16\times10^{-3}$

107. [0.63] Since velocity of PQ is constant. So emf developed across it remains constant.

$\varepsilon=B\ell v$ where ℓ = length of wire PQ

current at any time t is given by

$i=\frac{B\ell v}{R}\left(1-e^{\frac{Rt}{L}}\right)$

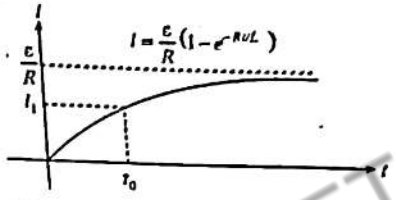
$I=\left(\frac{10}{100}\right)\times\left(\frac{1}{100}\right)\times\frac{1}{1}\left(1-e^{\frac{-1\times10^{-4}}{1\times10^{-4}}}\right)$

$=1\times\frac{1}{1000}=\frac{1}{1000}\times(1-e-1)$

$\therefore U=\frac{1}{2}L_1I_1^2+\frac{1}{2}L_2I_2^2+MI_1I_2\times(1-037)$

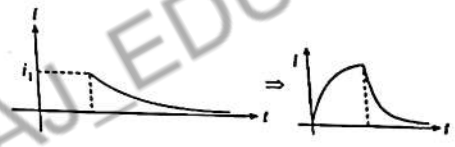
$I=0.63\times10^{-3}\,A\Rightarrow x=0.63$

108. (*) When S_1 is closed, current in circuit grows as



When at t_0, S_1 is opened & S_2 is closed then current decays as

$i=i_1e^{-Rt/L}$



No option is matching, hence this question is bonus.

JEE-Advanced

1. (c) In uniform magnetic field, change in magnetic flux is zero. Therefore, induced current will be zero.

2. (b) Power, $P=e^2/R$

Here, e = induced emf $=-\left(\frac{d\phi}{dt}\right)$

where, $\phi=NBA$

$e=-NA\left(\frac{dB}{dt}\right)$

$\therefore\ e^2\propto N^2$

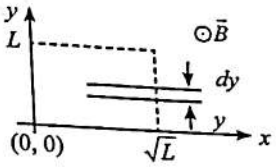
Also, $R\propto\frac{1}{r^2}$

As $R=\frac{\rho l}{A}=\frac{\rho l}{\pi r^2}$

where, R = resistance, r = radius

$\therefore\ P\propto N^2r^2\Rightarrow\frac{P_2}{P_1}=4$

3. (b,c,d) $y=x^2$, $V=V_0\,\hat{i}$, $B=B_0\left(1+\left(\frac{y}{2}\right)^\beta\right)\hat{k}$



end points are (0, 0) and $(\sqrt{L},L)$

Let at distance 'y' small length in y direction be dy

$\therefore\ d\varepsilon=V_0B\,dy$

$\therefore\ d\varepsilon=V_0B_0\left(1+\left(\frac{y}{L}\right)^\beta\right)dy$

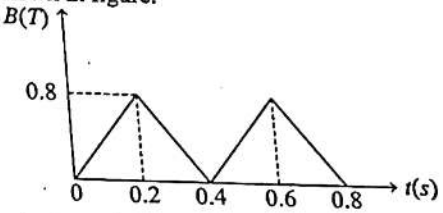
$=V_0B_0\left[\int_0^L y+\frac{y^{\beta+1}}{(\beta+1)L^\beta}\right]_0^L$

$e=V_0B_0\left[L+\frac{L^{\beta+1}}{(\beta+1)L^\beta}\right]$

$\Rightarrow\ \varepsilon=V_0B_0L\left(\frac{\beta+2}{\beta+1}\right)$

If $\beta=2$ then $\varepsilon=\frac{4}{3}\,V_0B_0L$

4. Magnetic field (B) varies with time (t) as shown in figure.



$\left|\frac{dB}{dt}\right|=\frac{0.8}{0.2}=4\text{T/s}$

Induced emf in the coil due to change in magnetic flux passing through it,

$e=\left|\frac{d\phi}{dt}\right|=NA\left|\frac{dB}{dt}\right|$

Here, A = Area of coil = $5\times10^{-3}\ m^2$

N = Number of turns = 100

Substituting the values, we get

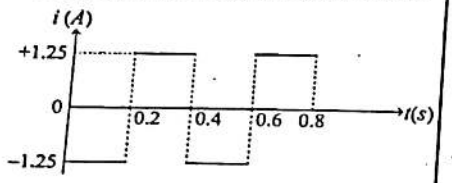
$e=(100)\,(5\times10^{-3})(4)=2\ V$

@FAKE_CBSE_X @RAJ_EDUNET

Therefore, current passing through the coil

$i = \frac{e}{R}$ or $i = \frac{2}{1.6} = 1.25A$

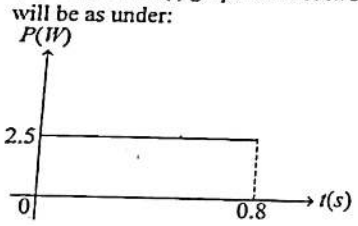
NOTE: That from 0 to 0.2 s and from 0.4 s to 0.6 s, magnetic field passing through the coil increases, while during the time 0.2s to 0.4s and from 0.6s to 0.8s magnetic field passing through the coil decreases. Therefore, direction of current through the coil in these two time intervals will be opposite to each other. The variation of current (i) with time (t) will be as follows:



Power dissipated in the coil is

$P = i^2R = (1.25)^2(1.6) = 2.5$ W

Power is independent of the direction of current through the coil. Therefore, power (P) versus time (t) graph for first two cycles will be as under:



Total heat obtained in 12,000 cycles will be

$H = P.t = (2.5)(12000)(0.4) = 12000$ J

This heat is used in raising the temperature of the coil and the water. Let Q be the final temperature. Then

$H = m_w s_w (\theta - 30) + m_c s_c (\theta - 30)$

Here,

m_w = mass of water = 0.5 kg

s_w = specific heat of water = 4200 J/kg-K

m_c = mass of coil = 0.06 kg

and s_c = specific heat of coil = 500 J/kg-K

Substituting the values, we get

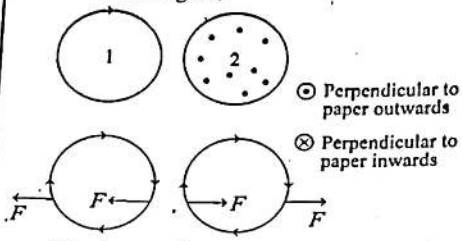
$12000 = (0.5)(4200)(\theta - 30) + (0.06)(500)(\theta - 30)$

or $\theta = 35.6°C$

5. (*d*) When switch S is closed magnetic field lines passing through Q increases in the direction from right to left. So, according to Lenz's law, induced current in Q i.e. I_{Q_1} will flow in such a direction, so that the magnetic field lines due to I_{Q_1} passes from left to right through Q.

This is possible when I_{Q_1} flows in anti-clockwise direction as seen by E. Opposite is the case when switch S is opened i.e. I_{Q_2} will be clockwise as seen by E.

6. (*c*) For understanding, let us assume that the two loops are lying in the plane of paper as shown. The current in loop 1 will produce ⊙ magnetic field in loop 2. Therefore, increase in current in loop 1 will produce an induced current in loop 2 which produces ⊗ magnetic field passing through it i.e. induced current in loop 2 will also be clockwise as shown in the figure.



The loops will now repel each other as the currents at the nearest and farthest points of the two loops flow in opposite directions.

7. (*a*)

8. (*d*)

9. (*c*)

10. When source is switched-off, left to right current decreases to zero. Therefore, from Lenz's law, induced current will oppose the change i.e. it will be from left to right if there is some inductance in the circuit, otherwise it will be zero.

11. Due to the current in A, a magnetic field is from right to left. When A is moved towards B, magnetic lines passing through B (from right to left) will increase, i.e. magnetic flux passing through B will increase. Therefore, current will be induced in B. The induced current will have such a direction that it gives a magnetic field opposite to that, passing through B due to current in A. Therefore, induced current in B will be in opposite direction of current in A.

12. (*b*) The moving rod develops an electric field = Bvl and the EMF induced is such that it opposes the change of magnetic field.

Due to shifting of electrons, one end of the rod becomes positive and the other end negative. This develops an electric field in the rod.

13. (*d*) P → 3, Q → 4, R → 2, S → 5

Induced emf $\varepsilon = B\ell v$

$\Rightarrow$ Induced current $i = \frac{\varepsilon}{R} = \frac{B\ell V}{R}$

$\Rightarrow mg - i\ell B = ma$ [Applying 2nd law]

$\Rightarrow mg - \frac{B^2\ell^2 v}{R} = m\frac{dv}{dt}$

$\Rightarrow \frac{dv}{mg - \frac{B^2\ell^2 v}{R}} = \frac{dt}{m}$

$\Rightarrow \frac{\ln\left[mg - \frac{B^2\ell^2 v}{R}\right]_0^v}{\frac{-B^2\ell^2}{R}} = \frac{t}{m}$

$\Rightarrow \frac{mg - \frac{B^2\ell^2 v}{R}}{mg} = e^{\frac{-B^2\ell^2}{mR}t}$

$\Rightarrow v = 2[1 - e^{-5t}]$

$\Rightarrow$ At $t = 0.2$ s, $v = 2\left[1 - \frac{1}{e}\right]$

$\Rightarrow \varepsilon = B\lambda \times 2\left[1 - \frac{1}{e}\right] = 1.2$ volts

And magnetic force = $i\ell B = 0.12$ N

And power dissipated = 0.144 W

Also, Terminal velocity = 2 m/s

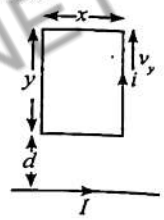
14. [4] Length of loop (y) = 4cm

Width of loop (x) = 2cm

Resistance of loop (R) = 0.1 W

Induced emf, $\varepsilon = (B_1 - B_2)xv_y$

Induce current



Induce current

$i = \frac{\varepsilon}{R} = \frac{\mu_0 I}{2\pi R}\left(\frac{1}{d} - \frac{1}{d+y}\right)xv_y$

$\Rightarrow 10\times10^{-6} = \frac{4\pi\times10^{-7}\times10}{2\pi\times0.1}\left[\frac{1}{4} - \frac{1}{8}\right]\times2\cdot v_y$

$\therefore V_y = 2$

$\tan\theta = \frac{v_y}{v_x} = \frac{1}{\sqrt{3}} \Rightarrow v_x = v_x\sqrt{3}$

$\therefore v_x = 2\sqrt{3}$

Value of velocity,

$\therefore v = \sqrt{v_x^2 + v_y^2}$

$= \sqrt{(2\sqrt{3})^2 + (2)^2} = \sqrt{16} = 4$ m/s

15. [0.02] Magnetic Flux, $\phi = BLx$

Induced EMF, $E = \frac{d\phi}{dt} = BLv_0$

Total resistance of the loop, R = 1Ω + 3Ω = 4Ω

(Using Wheatstone bridge theory)

$= 10^{-3} = \frac{BLv_0}{4}$

$v_0 = 0.02$ m/s

@TAKE CBSE TO NEXT LEVEL

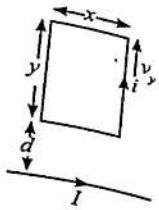
$$\frac{mg - \frac{B^2\ell^2 v}{R}}{mg} = e^{\frac{-B^2\ell^2}{mR}t}$$

$v = 2[1 - e^{-5t}]$

At $t = 0.2$ s, $v = 2\left[1 - \frac{1}{e}\right]$

$= B\lambda \times 2\left[1 - \frac{1}{e}\right] = 1.2$ volts

magnetic force $= i\ell B = 0.12$ N
power dissipated $= 0.144$ W
Terminal velocity $= 2$ m/s
of loop $(y) = 4$cm
of loop $(x) = 2$cm
nce of loop $(R) = 0.1$ W
l emf, $\varepsilon = (B_1 - B_2)xv_y$
current



rent

$\frac{\mu_0 I}{\pi R}\left(\frac{1}{d} - \frac{1}{d+y}\right)xv_y$

$\frac{10^{-7} \times 10}{0.1}\left[\frac{1}{4} - \frac{1}{8}\right] \times 2 \cdot v_y$

$= \frac{1}{\sqrt{3}} \Rightarrow v_x = v_x\sqrt{3}$

ity,

$\frac{2}{y}$

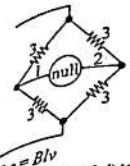
$\sqrt{(2)^2} = \sqrt{16} = 4$ m/s

x, $\phi = BLx$

$\frac{d\phi}{dt} = BLv_0$

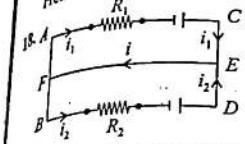
ıe loop, $R = 1\Omega + 3\Omega$

ridge theory)



16. [1] $\varepsilon = Blv$
$= (0.2 \times 10^{-4})(1)(180 \times 5/18)$
$= 10^{-3}V = 1mV$

17. [False] When conducting rod AB moves parallel to x-axis in a uniform magnetic field pointing in the positive z direction, then according to Fleming's left-hand rule, the electrons will experience a force towards B.
Hence, the end A will become positive.

18. 

Let m = mass of bar, L = length
v = velocity of the bar = dx/dt
e = emf induced in the upper circuit.
= emf induced in the lower circuit = BLV
i = current flowing through the rod.
F_{m-g} magnetic force acting on the rod = BLI.
The direction of current in the circuit is shown in the figure, when terminal velocity is attained

$BiL = mg$

$\therefore i = \frac{mg}{BL} = \frac{0.2 \times 9.8}{1 \times 0.6} = 3.267\,A$

Power dissipated in $R_1 = ei_1 = 0.76$ W
Power dissipated in $R_2 = ei_2 = 1.2$ W
Total power dissipated $= e(i_1 + i_2)$
$\Rightarrow e = 1.96$ W

$\Rightarrow e = \frac{1.96}{1} = \frac{1.96}{3.267} = 0.6\,V \Rightarrow e = BLV$

$\therefore V = \frac{e}{BL} = \frac{0.6}{0.6 \times 1} = 1m/s$

Terminal velocity $= 1m/s$

Further $\frac{e^2}{R_1} = 0.76$

$\Rightarrow R_1 = \frac{e^2}{0.76} = \frac{0.6 \times 0.6}{0.76} = 0.474\Omega$

Similarly,

$R_2 = \frac{e^2}{1.2} = \frac{(0.6)^2}{1.2} = 0.3\Omega$

19. Flux through $AEFD$, $\phi = BA$ & through $EBCF$ $\phi_2 = BA_2$
$A_1 = 1 \times 1 = 1\text{m}^2$
& $A_2 = 1 \times \frac{1}{2}m^2 = \frac{1}{2}m^2$

Also, the magnitude of induced emf will be

$e_1 = \left|\frac{d\phi_1}{dt}\right| = A_1\frac{dB}{dt} = 1V$ (given $\frac{dB}{dt} = 1$)

$e_2 = \left|\frac{d\phi_2}{dt}\right| = A_2 = \frac{dB}{dt} = \frac{1}{2}$ or $0.5V$

Since, the magnetic field. is Increasing & directed into the paper, hence the induced current in these loops should be in anti-clockwise dirt.
The equivalent circuit will be given as On applying Kirchhoff's voltage. Law in these loops

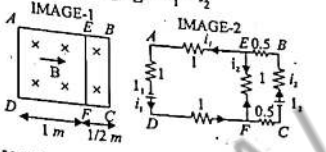
$4i_1 - i_2 = e_1$
$3i_2 - i_1 = e_2$

$i_1 = \frac{7}{22}A$

$i_2 = \frac{6}{22}A$

$i_1 - i_2 = \frac{1}{22}A$

$i_{AE} = i_1, i_{BE} = i_2, i_{EF} = i_1 - i_2$



20. [15] We will write voltage drop equation as we go from A to B.

$V_A - iR + V + L\frac{di}{dt} = V_B$

$V_A - 5 \times 1 + 15 - 5 \times 10^{-3} \times (-10^3) = V_B$
$V_B - V_A = 15$

21. (b) When the magnet is moved, it creates a state where the plate moves through the magnetic flux, due to which an electromotive force is generated in the plate and eddy currents are induced. These currents are such that it opposes the relative motion $\Rightarrow$ disc will rotate in the direction of rotation of magnet.
Note: This apparatus is called Arago's disk.

22. (c) motional emf $= Brl$
for semi circle
$l = 2R$
$\therefore e = B\,2RV$
For getting higher potential, use right palm rule
$\therefore Q$ will be at higher potential

23. (d) The change in magnetic flux associated with the loop is zero as B is uniform everywhere.
As there is no change in flux, induced EMF is zero and therefore no current induced.

24. (b,d) Initial condition
$\phi_1 = AB, \phi_2 = 2AB$
General form
$\phi_1 = AB\cos\omega t$
$\phi_2 = 2AB\cos\omega t$

$\therefore E_1 = \frac{-d\phi_1}{dt} = AB\omega\sin\omega t$ ...(1)

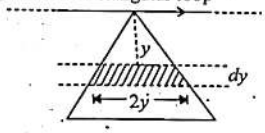
$E_2 = 2AB\omega\sin\omega t$ ...(2)

Now, the emf induced in the two loops have opposite polarizing because of the given orientation of the wires.

$\therefore |E_{net}| = |E_1 - E_2| = AB\omega\sin\omega t$

Option A is Incorrect.
Rate of change of flux = emf induced is proportional to sin wt from (1) and (2).
Therefore, induced emf in the loop = $AB\omega\sin\omega t$ proportional to sum of areas.
It is proportional to difference of the areas.
Rate of change of the flux is maximum which implies emf is maximum.
$AB\omega\sin\omega t$ is maximum after one fourth and threefourth of the revolution, when the loop is perpendicular.

25. (a,c) By reciprocity theorem of mutual induction, it can be assumed that current in infinite wire is varying at 10A/s and EMF is induced in triangular loop



Flux of magnetic field through triangle loop, if current in infinite wire is φ, can be calculated as follows

$d\phi = \frac{\mu_0 i}{2\pi y}.2ydy$

$d\phi = \frac{\mu_0 i}{\pi}dy$

$\phi = \frac{\mu_0 i}{\pi}\left(\frac{l}{\sqrt{2}}\right)$

$\text{EMF} = \left|\frac{d\phi}{dt}\right| = \frac{\mu_0}{\pi}\left(\frac{1}{\sqrt{2}}\right).\frac{di}{dt}$

$= \frac{\mu_0}{\pi}(10cm)\left(10\frac{A}{s}\right) = \frac{\mu_0}{\pi}$ volt

If we assume the current in the wire towards right then as the flux in the loop increases we know that the induced current in the wire is counter clockwise. Hence, the current in the wire is towards right.
Field due to triangular loop at the location of infinite wire is into the paper. Hence, force on infinite wire is away from the loop.
By cylindrical symmetry about infinite wire, rotation of triangular loop will not cause any additional EMF.
Answer is option a and c.

@FAKE_CBSE_@RAJ_BHAI

26. (*b, d*) When current is switched on an induced current is produced in the ring in opposite direction. So repulsive force or impulse will act on ring. This impulse (say J) is proportional to induced current in the loop. Hence $J = \alpha I = \Delta P = mv$ and $v = \sqrt{2gh}$

$$\therefore \quad h \propto \frac{I^2}{m^2}$$

For identical rings induced emf will be same.

If $\rho_A < \rho_B$, then $I_A > I_B$. In this case given condition can be fulfilled if $m_A \leq m_B$.

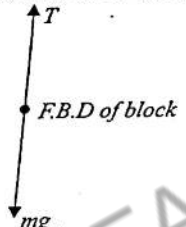
27. (*d*) The square loop *ABCD* is a metallic loop. So it consists of the free electrons. When the loop moves in a magnetic field, the free electrons in the *AD* and *BC* rod will experience the Lorentz force and they will move towards the ends creating a potential difference in the rods.

This induced emf leads to the electric field induced in the rods *AD* and *BC* of the square loop. But there will be no current flowing in the loop as net potential difference is zero.

28. [False] If the coil is kept stationary in the uniform magnetic field, there will be no change in the magnetic flux linked with the coil. Therefore, there will be no induced emf in coil.

Since, there is no induced emf, there will be no induced current also in the coil.

29. Let v be the velocity of rod at any instant 't'.



$T = ILB$

Hence, for body of mass m,

$$a = \frac{dv}{dt} = \frac{mg - |IBL}{m}$$

$$1 = \frac{Induced\ emf}{R} = \frac{BvL}{R}$$

$$\Rightarrow a = \frac{dV}{dt} = \frac{mg - \left(\frac{BvL}{R}\right)(LB)}{m} = \frac{mg - \left[\frac{B^2L^2v}{R}\right]}{m}$$

(*a*) When velocity becomes constant, $a = 0$ and corresponding terminal velocity is

$$v_T = \frac{mgR}{B^2L^2}$$

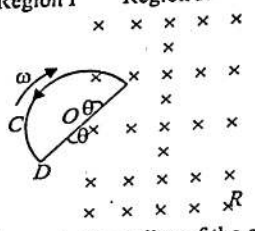
(*b*) When, $v = \frac{V_T}{2} = \frac{mgR}{2 \cdot 2B^2L^2}$

$$a = \frac{mg - \frac{B^2L^2}{R}\left(\frac{mgR}{2B^2L^2}\right)}{m} = g - \frac{g}{2} = \frac{g}{2}$$

30. (*a*) Let at any instant, the position of the loop be as shown in the diagram.

At this instant the flux through the loop is,

$\phi = BA = B(1/2r^2\theta)$



where r is the radius of the conducting loop, hence the induced emf is,

$E = -d\phi/dt$

$$= -\frac{1}{2}\frac{d}{dt}(Br^2\theta) = -\frac{1}{2}Br^2\omega$$

After each half rotation from the line separating two regions, the polarity of the induced emf will change as increasing flux will change to decreasing flux and vice-versa,

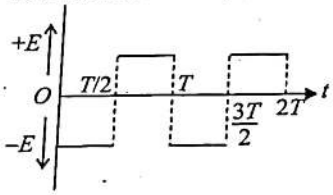
$$\therefore E = \frac{1}{2}(-1)^n Br^2\omega$$

Where ω is the angular velocity with which the loop is rotated and $n = 1, 2, 3\ldots$ is the number of the half-revolution that the loop performs at the given moment.

Correspondingly, the induced current in this loop of resistance R, is

$$I = \frac{E}{R} = \frac{1}{2}(-1)^n \frac{Br^2\omega}{R}$$

(*c*) Graph between the induced emf and the time of rotation for two periods of rotation will be



31. (*d*) The current will be in an anticlockwise sense as a magnetic field is increasing into the plane of the paper.

The induced magnetic field has to be out of the plane of the paper.

Hence, the current in the segment ab will be from b to a, and current in the segment cd will be d to c.

32. (*b*) The polarity of induced emf will be opposite in the two cases while entering and while leaving the coil.

33. (*b*) The induced electric field is given by:

$$\oint \vec{E} \cdot d\vec{l} = -\int \frac{d\vec{B}}{dt} \cdot d\vec{A}$$

$$\Rightarrow |E|(2\pi r) = \frac{dB}{dt} \cdot \pi a^2 \Rightarrow |E| \propto \frac{1}{r}.$$

34. (*d*) Total magnetic flux passing through whole of the $x - y$ plane will be zero, because magnetic lines form a closed loop. So, as many lines will move in $-z$ direction same will return to $+z$ direction from the $x - y$ plane

35. [7] The magnetic field due to current carrying wire at the location of square loop is

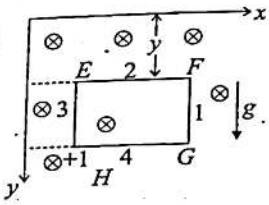
$$B = \frac{\mu_0}{4\pi} \frac{2\pi iR^2}{\left(R^2 + 3R^2\right)^{3/2}} = \frac{\mu_0 i}{16R}$$

The mutual induction

$$M = \frac{N\phi}{i} = \frac{2}{i}\left[\frac{\mu_0 i}{16R} \times a^2 \cos 45°\right]$$

$$\therefore M = \frac{\mu_0 a^2}{2^{7/2} R} \quad p = 7$$

36.



Flux through loop *EFGH* at a distance of y from x-axis

$$\phi = \int_y^{y+a} B \cdot a \cdot dy = \int_y^{y+a} B_0 \cdot \left(\frac{y}{a}\right) a \cdot dy$$

$$= \frac{B_0}{2}[(y+a)^2 - y^2]$$

(*a*) Induced emf $= -\frac{d\phi}{dt} = -B_0[(y+a) - y]\frac{dy}{dt}$

$$= -B_0 a v_y$$

Current will be anticlockwise and its value will be:

$$= \frac{|emf|}{R} = \frac{B_0 a v_y}{R}$$

(*b*) $\vec{F}_{EF} = 1\int_E^F d\vec{l} \times \vec{B} = 1\left[\left(-a\hat{i}\right) \times \frac{B_0 y}{a}\hat{k}\right] = \left|B_0 y\hat{j}\right.$

@FAKE_CBSE_GRAJ_EDUNET

...site in the two cases while entering ... induced emf will be ... while leaving the coil.

...duced electric field is given by:

$\oint \vec{E} = -\int \frac{d\vec{B}}{dt} \cdot d\vec{A}$

$E(2\pi r) = \frac{dB}{dt} \cdot \pi a^2 \Rightarrow |E| \propto \frac{1}{r}$

...agnetic flux passing through ... the $x-y$ plane will be zero, ... magnetic lines form a closed ..., as many lines will move ... ection same will return to ... from the $x-y$ plane

...netic field due to current ... wire at the location of square

$\frac{2\pi i R^2}{\left(z^2+3R^2\right)^{3/2}} = \frac{\mu_0 i}{16R}$:

induction

$\frac{2}{i}\left[\frac{\mu_0 i}{16R} \times a^2 \cos 45^\circ\right]$

$\frac{}{R}$ $P = 7$

$\longrightarrow x$

$\odot$

$\otimes$ g

$EFGH$ at a distance of

$\int_y^{y+a} B_0 \cdot \left(\frac{y}{a}\right) a \cdot dy$

$\frac{d\phi}{dt} = -B_0[(y+a)-y]\frac{dy}{dt}$

$B_0 a v_y$

anticlockwise and its

$\left[\left(-a\hat{i}\right) \times \frac{B_0 y}{a}\hat{k}\right] = \left|B_0 y\right|\hat{j}$

$\vec{F}_{FG} = i\int_F^G d\vec{l} \times \vec{B}$

$\vec{F}_{GH} = i\int_G^H d\vec{l} \times \vec{B} = -lB_0(y+a)\hat{j}$

$\vec{F}_{HE} = i\int_H d\vec{l} \times \vec{B} = -\vec{F}_{GH}$

$\therefore F_{Net} = -lB_0(y+a)\hat{j} + \left|B_0 y\right|\hat{j} = -\frac{B_0^2 a^2 v_y}{R}\hat{j}$

(c) $m\frac{dv_y}{dt} = mg - \frac{B_0^2 a^2}{R} v_y$

$\int_0^v \frac{dv_y}{g - \frac{B_0^2 a^2}{mR} v_y} = \int_0^t dt$

$v = \frac{mgR}{B_0^2 a^2}\left(1 - e^{-\frac{B_0^2 a^2}{mR} t}\right)$

$v_T = \frac{mgR}{B_0^2 a^2}$

37. As the current increases, the number of magnetic lines of force passing through the loop increases in the outward direction. To oppose this change, the current will flow in the clockwise direction.
This is the required answer.

38. (a) Mutual induction flux linkage between coils
1. flux linkage in coil (a) is maximum because both coils have same axis.
2. Flux linkage between coils is 0 because thus axis are perpendicular to each other.
3. Flux linkage between coils is 0 because their axis are perpendicular to each other.
4. So, mutual inductance between coils is maximum in case (A).

39. (b) Field at the center of outer square loop $= B = \frac{2\sqrt{2}\mu i}{\pi L}$ along the axis.
flux linking the smaller square loop
$= \lambda = Bl^2 = \frac{2\sqrt{2}\mu i}{\pi L} l^2$
mutual inductance $= m\frac{\lambda}{i} = \frac{2\sqrt{2}\mu l^2}{\pi L}$

40. (a,c,d) Correct options are a, c and d
We know $e = L\frac{di}{dt} \propto L$
So, $\frac{e_1}{e_2} = \frac{L_1}{L_2} = \frac{8}{2} = \frac{4}{1}$
Since $P = ei$ = Constant
Therefore, $\frac{di_1}{dt} = \frac{di_2}{dt}$

$P_1 = P_2 = P$
$e_1 i_1 = e_2 i_2$
Therefore, $\frac{di_1}{dt} = \frac{di_2}{dt}$
$P_1 = P_2 = P$
$e_1 i_1 = e_2 i_2$
$\therefore \frac{i_1}{i_2} = \frac{e_2}{e_1} = \frac{1}{4}$
Thus, ratio of current is 1:4
$W = \frac{1}{2}Li^2$
Energy stored
$\frac{W_2}{W_1} = \left(\frac{L_2}{L_1}\right)\left(\frac{i_2}{i_1}\right)^2 = \left(\frac{1}{4}\right)(4)^2$
$\frac{W_1}{W_2} = \frac{1}{4}$

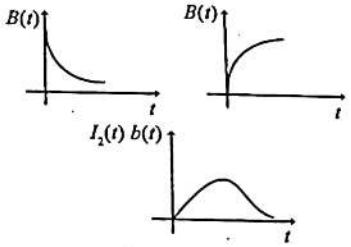
41. For resistance, is broken into two identical, $R_1 = R_2 = 3\Omega$
Equivalent resistance in parallel combination,
$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$
$\frac{1}{R_{eq}} = \frac{1}{3} + \frac{1}{3} = \frac{2}{3}$
$R_{eq} = \frac{3}{2} = 1.5\Omega$
For self inductance, $1.8\times10^{-4} H$ is broken into two identical
$L_1 = L_2 = 0.9\times10^{-4} H$
Equivalent self inductance in parallel combination,
$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2}$
$\frac{1}{L_{eq}} = \frac{1}{0.9\times10^{-4}} + \frac{1}{0.9\times10^{-4}} = \frac{2}{0.9\times10^{-4}}$
$L_{eq} = \frac{0.9\times10^{-4}}{2} = 4.5\times10^{-5} H$
$\tau = \frac{L_{eq}}{R_{eq}} = \frac{4.5\times10^{-5}}{1.5} = 3\times10^{-5}$ sec
steady current $I = \frac{E}{R_{eq}} = \frac{15}{1.5} = 10A$

42. [55] Mutual inductance is producing flux in same direction as self inductance.
$\therefore U = \frac{1}{2}L_1 I_1^2 + \frac{1}{2}L_2 I_2^2 + MI_1 I_2$
$\Rightarrow U = \frac{1}{2} \times (10\times10^{-3})1^2 + \frac{1}{2} \times (20\times10^{-3}) \times 2^2 + (5\times10^{-3}) \times 1 \times 2$
$= 55$ mJ

43. (b) After using the values from the options, we find out the charge on the capacitor as
$Q = Q_0(1 - e^{-t/\tau})$
$Q = CV(1 - e^{-1})$ after time interval 2τ

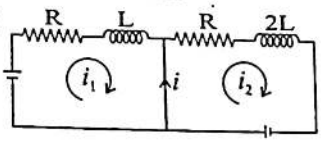
44. (c) If the charge at any instant on capacitor is Q and current through inductor is I, then as per KVL,
$\frac{Q}{C} + L\frac{dI}{dt} = 0$
Since $I = \frac{dQ}{dT}$
Substituting above, we get
$Q = -LC\frac{d^2Q}{dt^2}$.

45. (d) The equations of $I_1(t)$, $I_2(t)$ and $B(t)$ will take the following forms:
$I_1(t) = K_1(1 - e^{-k_1 t}) \rightarrow$ current growth in L-R circuit
$B(t) = K_3(1 - e^{-k_3 t}) \rightarrow B(t) \propto I_1(t)$
$I_2(t) = K_4 e^{-k_2 t}$
$\left[I_2(t) = \frac{e_2}{R}$ and $e_2 \propto \frac{dI_1}{dt} : e_2 = -M\frac{dI_1}{dt}\right]$
Therefore, the product $I_1(t)\ B(t) = K_3 e^{-k_2 t}(1 - e^{-k_3 t})$.
The value of this product is zero at $t = 0$ and $t = \infty$. Therefore, the product will pass through a maximum value. The corresponding graphs will be as follows:



46. (d) For a DC $L - R$ circuit, current in the inductor grows as per below relationship,
$I(t) = I_0(1 - e^{-t/\tau})$
Here, $I_0 = \frac{V}{R} = \frac{12}{6} = 2A$, is the steady-state current through the circuit.
$\tau = L/R = \frac{8.4}{6} = 1.4ms$, is the time constant.
So, $I(t) = 1A \Rightarrow 2(1 - e^{-t/1.4}) = 1$
$\Rightarrow e^{-t/1.4m} = 0.5$
Taking logarithm of both sides,
$-\frac{t}{1.4m} = -0.693$
$\Rightarrow t = 0.97$ ms ≈ 1 ms

47. (b, d)



@FAKE_CBSE_YOGRAJ_EDUNET

$I_{max} = (I_2 - I_1)_{max}$

$\Delta I = (I_2 - I_1) = \frac{V}{R}\left[1 - e^{-\left(\frac{R}{2L}\right)t}\right] - \frac{V}{R}\left[1 - e^{-\left(\frac{R}{L}\right)t}\right]$

$\Delta I = \frac{V}{R}[e^{-(R/L)} - e^{-(R/2L)}]$

Now $(\Delta i)_{max} \Rightarrow \frac{d(\Delta i)}{dt} = 0$

$\frac{V}{R}\left[-\frac{R}{L}e^{-\left(\frac{R}{L}\right)t} - \left(-\frac{R}{2L}\right)e^{-\left(\frac{R}{2L}\right)t}\right] = 0$

$e^{-\left(\frac{R}{L}\right)t} = \frac{1}{2}e^{-\left(\frac{R}{2L}\right)t}$

$e^{-\left(\frac{R}{2L}\right)t} = \frac{1}{2} \Rightarrow \left(\frac{R}{2L}\right)t = ln2, at\ t = \tau$

$\tau = \frac{2L}{R}ln2 \rightarrow$ time when is maximum

$I_{max} = \frac{V}{R}[e^{-\frac{R}{L}(\frac{2L}{R}(n2)} - e^{-\left(\frac{R}{2L}\right)\left(\frac{2L}{R}(n2)\right]}$

$|I_{max}| = \frac{V}{R}\left[\left[\frac{1}{4} - \frac{1}{2}\right]\right] = \frac{1}{4}\frac{V}{R}$

So the second and the fourth options are the correct ones.

48. [100] For lamp,

$p = \frac{V^2}{R}$

$R = \frac{100 \times 100}{500} = 20\Omega$

$i = \frac{V}{R} = \frac{100}{20} = 5A \Rightarrow i = \frac{V}{\sqrt{R^2 + X_C^2}}$

$\Rightarrow 5 = \frac{200}{\sqrt{(20)^2 + \left(\frac{1}{2\pi \times 30 \times C}\right)^2}}$

$\Rightarrow 400 + \left(\frac{1}{100\pi C}\right)^2 = 1600$

$\Rightarrow \left(\frac{1}{100\pi C}\right)^2 = 1200 \Rightarrow \frac{1}{\pi^2 C^2} = 1200 \times 10^4$

$\Rightarrow (\pi C)^2 = \frac{1}{12} \times 10^{-6}$

$\Rightarrow C^2 = \frac{1}{12\pi^2} \times 10^{-6}$

$\Rightarrow C = \frac{1}{\sqrt{12}\pi} \times 10^{-3} = 100 \times 10^{-6}\,F = 100\mu F$

49. [60] For lamp,

$p = \frac{V^2}{R}$

$R = \frac{100 \times 100}{500} = 20\Omega$

$i = \frac{V}{R} = \frac{100}{20} = 5A \Rightarrow i = \frac{V}{\sqrt{R^2 + X_C^2}}$

$\Rightarrow 5 = \frac{200}{\sqrt{(20)^2 + \left(\frac{1}{2\pi \times 30 \times C}\right)^2}}$

$\Rightarrow 400 + \left(\frac{1}{100\pi C}\right)^2 = 1600$

$\Rightarrow \left(\frac{1}{100\pi C}\right)^2 = 1200 \Rightarrow \frac{1}{\pi^2 C^2} = 1200 \times 10^4$

$\Rightarrow (\pi C)^2 = \frac{1}{12} \times 10^{-6}$

$\Rightarrow C^2 = \frac{1}{12\pi^2} \times 10^{-6}$

$\Rightarrow C = \frac{1}{\sqrt{12}\pi} \times 10^{-3} = 100 \times 10^{-6}\,F = 100\mu F$

$V = \sqrt{V_C^2 + V_R^2}$

$200 = \sqrt{V_C^2 + 100^2}$

$\Rightarrow V_C = 100\sqrt{3}$

$\tan\phi = \frac{X_C}{R} = \frac{V_C}{V_R} = \frac{100\sqrt{3}}{100} = \sqrt{3}$

$\phi = 60°$

50. (*b*) The induced electric field is given by,

$\oint E \cdot dl = -\frac{d\phi}{dt}$ or $El = -S\left(\frac{dB}{dt}\right)$

$\therefore E(2\pi R) = -(\pi R^2)(B)$ or $E = -\frac{BR}{2}$

$\therefore |E| = \frac{BR}{2}$

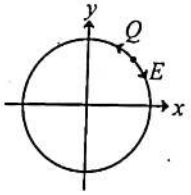
51. (*b*) $\frac{M}{L} = \frac{Q}{2m}$

$\therefore M = \frac{Q}{2m}L \Rightarrow M \propto L,$

where $\gamma = \left(\frac{Q}{2m}\right)$

$M = \left(\frac{Q}{2m}\right)(I\omega)$

$= \left(\frac{Q}{2m}\right)(mR^2\omega) = \frac{Q\omega R^2}{2}$



Induced electric field is opposite direction. Therefore,

$\omega' = \omega - \alpha t$

$\alpha = \frac{\tau}{I} = \frac{(QE)R}{mR^2} = \frac{(Q)\left(\frac{BR}{2}\right)R}{mR^2} = \frac{QB}{2m}$

$\therefore \omega' = \omega - \frac{QB}{2m} \cdot 1 = \omega - \frac{QB}{2m}$

$M_f = \frac{Q\omega' R^2}{2} = Q\left(\omega - \frac{QB}{2m}\right)\frac{R^2}{2}$

$\therefore \Delta M = M_f - M_i = -\frac{Q^2BR^2}{4m}$

$M = -\gamma\frac{QBR^2}{2} \quad \left(\because \gamma = \frac{Q}{2m}\right)$

52. [0.63] Since velocity of PQ is constant. So emf developed across it remains constant.

$\varepsilon = B\ell v$ where ℓ = length of wire PQ current at any time t is given by

$i = \frac{B\ell v}{R}\left(1 - e^{\frac{Rt}{L}}\right)$

$i = \left(\frac{10}{100}\right) \times \left(\frac{1}{100}\right) \times \frac{1}{1}\left(1 - e^{\frac{-1\times10^{-3}}{1\times10^{-3}}}\right)$

$= 1 \times \frac{1}{1000} = \frac{1}{1000} \times (1 - e - 1)$

$= \therefore U = \frac{1}{2}L_1I_1^2 + \frac{1}{2}L_2I_2^2 + MI_1I_2$

$i = 0.63 \times 10^{-3}\,A \Rightarrow x = 0.63$ $\times (1-0.37)$

53. [8] $i_{min} = \frac{5}{12}$ at $t = 0$

$i_{max} = \frac{5 \times 8}{12}$ at $t = \infty$

$\frac{i_{max}}{i_{min}} = 8$

This is the required answer.

54. [3.5] Given that,

$L = 10H$

$R = 2\Omega$

$V = 10V$

Now, the maximum current is

$i_0 = \frac{V}{R}$

$i_0 = \frac{10}{2}$

$i_0 = 5\,A$

The maximum energy is $E_0 = \frac{1}{2}Li_0^2$

$E_0 = \frac{1}{2} \times 10 \times 5 \times 5 = E_0 = 125J$

Now, the magne...

$E = \frac{E_0}{4} = E = \frac{125}{4}$

Now, $E = \frac{1}{2}Li^2$

$\frac{125}{4} = \frac{1}{2}Li^2$

$i^2 = \frac{25}{4}$

$i = \frac{5}{2} = i = 2.5\,A$

Now, the time t
0 – 2.5A.
We know that,
during its grow

$i = i_0\left(1 - e^{\frac{Rt}{L}}\right.$

$2.5 = 5\left(1 - e^{-}\right.$

$e^{\frac{-Rt}{L}} = 0.5$

$\frac{-Rt}{L} = ln(0.$

$\frac{Rt}{L} = 0.693$

$t = \frac{6.93}{2} =$

$t = 3.5$ sec

Hence, th

increases
3.5sec.

55. After a lo
which im
(ωL for

capacita

equivale
is show

$R_{net} =$

Net int
∴ Cur

$I = \frac{}{}$
$\frac{3}{4}$

The p
of cel
$E = I$

$E =$

©FAKE_CBSE_X_ORAJ_EDUNET

Now, the magnetic energy

$$E = \frac{E_0}{4} = E = \frac{125}{4} J$$

Now, $E = \frac{1}{2} Li^2$

$$\frac{125}{4} = \frac{1}{2} Li^2$$

$$i^2 = \frac{25}{4}$$

$$i = \frac{5}{2} = i = 2.5\,A$$

Now, the time taken to rise current from $0 - 2.5A$.

We know that, the instantaneous current during its growth in an L-R circuit,

$$i = i_0\left(1 - e^{-\frac{Rt}{L}}\right)$$

$$2.5 = 5\left(1 - e^{-\frac{Rt}{L}}\right)$$

$$e^{\frac{-Rt}{L}} = 0.5$$

$$\frac{-Rt}{L} = ln(0.5)$$

$$\frac{Rt}{L} = 0.693$$

$$t = \frac{6.93}{2} = t = 3.46$$

$t = 3.5$ sec

Hence, the magnetic energy will be increases to $\frac{1}{4}$ of the maximum value at 3.5sec.

55. After a long time, steady state is reached in which impedance due to inductor (ωL for dc) is zero and that due to capacitance $\frac{1}{\omega C}$ becomes infinite, so equivalent circuit is shown in figure Net external resistance

$$R_{net} = \frac{\frac{R}{2} + R}{2} = \frac{3R}{4}$$

Net internal resistance $R_{int} = r_1 + r_2$

$\therefore$ Current in circuit

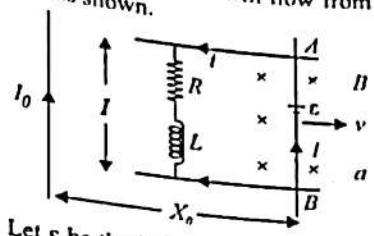
$$I = \frac{2E}{\frac{3}{4}R + r_1 + r_2}$$

The potential difference across the terminals of cell A is zero; So,

$E = Ir_1 = 0$

$$E - \frac{2Er_1}{\frac{3}{4}R + r_1 + r_2} \Rightarrow R = \frac{4}{3}(r_1 - r_2)$$

56. (*a*) When bar AB slides away, the magnetic force acts on free electrons along negative Y-axis, so electrons move from end A to end B, making end A at positive potential relative to end B. So current in the circuit will flow from B to A as shown.



Let ε be the induced emf according to Kirchhoff's second law,

$$-Ri - L\frac{di}{dt} + \varepsilon = 0 \Rightarrow \varepsilon = Ri + L\frac{di}{dt}$$

But $\varepsilon = \frac{d\phi}{dt}$ (numerically) ....(*i*)

This is the required relation.

(*b*) Equation (*i*) can be expressed as

$d\phi = Ridt + Ldi \Rightarrow d\phi = Rdq + Ldi$

Integrating, we get

$$\int_0^T d\phi = R\int_0^q dq + L\int_0^{i_1} di$$

$$[\phi]_{t=0}^{T} = Rq + Li_1$$

$\therefore$ Charge flown from $t = 0$ to $t = T$ will be ...(*ii*)

Change in flux during the displacement of bar from $x = x_0$ to $x = 2x_0$ in time T is $\phi(T) - \phi(0)$

$$= \int_{x_0}^{2x_0} BdA = \int_{x_0}^{2x_0} \frac{\mu_0 I_0}{2\pi x} ldx$$

$$= \frac{\mu_0 I_0 l}{2\pi} log_e 2 \qquad ...(iii)$$

$\therefore$ From Eq. (*ii*), charge flown

$$q = \frac{\mu_0 I_0 l}{2\pi R} log_e 2 - \frac{Li_1}{R} \qquad ...(iv)$$

(*c*) The equation of decay of current in an circuit is given by

$i = i_0 e^{-Rt/L}$ ...(*v*)

Given $i = \frac{i_1}{4}, i_0 = i_1, t = 2T - T = T$

Substituting these values in Eq. (*v*), we get

$$\frac{i_1}{4} = i_1 e^{-RT/L} \Rightarrow e^{-RT/L} = \frac{1}{4}$$

$$or\ \frac{RT}{L} = log_e 4 \therefore \frac{L}{R} = \frac{T}{log_e 4}$$

57. (*a*) In the branch containing L and R_2

$$i = \frac{E}{R_2}\left(1 - e^{-\frac{R_2 t}{L}}\right)$$

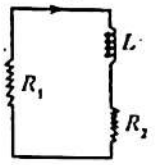
$$\frac{di}{dt} = \frac{E}{R_2} e^{-\frac{R_2 t}{L}} \cdot \frac{R_2}{L} = \frac{E}{L} e^{-\frac{R_2 t}{L}}$$

$$\therefore V_L = L\frac{di}{dt} = Ee^{-\frac{R_2 t}{L}}$$

$$= 12e^{-\frac{2t}{400\times10^{-3}}} = 12e^{-5t} V$$, this is the voltage drop across L as a function of time.

(*b*) Steady state current (R_1 short circuited)

$$I_0 = \frac{E}{R_2} = 6A$$



As the switch is open, current through R_1 becomes low instantly but current through R_2 decays exponentially.

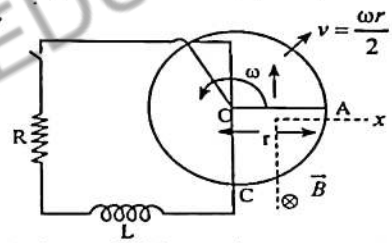
Now, time constant

$$\tau^1 = \frac{L}{R_1 + R_2} = \frac{0.4}{2+2} = 0.15$$

$\therefore$ Current through R_1 at time t

$i = i_0 e^{-t/\tau^1} = 6\times e^{-10t}$ A (upward)

58.



When switch is not closed current through circuit is zero and EMF induced in the rod is equal to the emf induced across switch.

for small section 'dx'

induced emf $\Rightarrow de = Bv\,dx$

$de = Bx\,wdx$

$$\therefore \int de = \int_0^r Bwxdx$$

$$e = \frac{B\omega r^2}{2}$$ [0 at higher potential]

(*i*) When switch S closed current through the circuit i

$$I = I_0(1 - e^{-t/\tau}) \text{ where } I_0 = \frac{e}{R}$$

$$\therefore I = \frac{Bwr^2}{2R}(1 - e^{-Rt/L})$$

Here $T = \frac{L}{R}$ (Time constant) current flows anticlockwise.

(*ii*) Electromagnetic force F_m act and equal to $F_m = idl\ F_m = idl \times \vec{B} = irB$ downward direction between the OA.

@FAKE-CBSE-X@RD_EDUNET

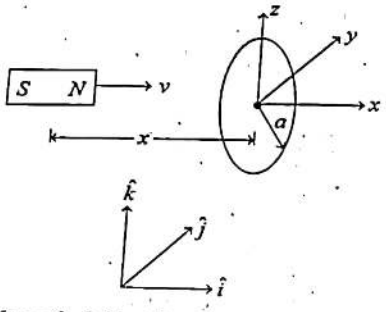
Required torque

$$\tau = \tau_{F_B} + \tau_{mg} = F_B\frac{r}{2} + mg\frac{r}{2}\cos\theta$$

$$= \frac{EBr^2}{2R} + \frac{mgr}{2}\cos wt$$

$$\tau = \frac{B^2wr^4}{4R} + \frac{mgr\cos wt}{2}$$

59. Given that $x >> a$.



Magnetic field at the centre of the coil due to the bar magnet is

$$B = \frac{\mu_0}{4\pi}\frac{2M}{x^3} = \frac{\mu_0}{2\pi}\frac{M}{x^3}$$

Due to this, magnetic flux linked with the coil will be,

$$\phi = BS = \frac{\mu_0}{2\pi}\frac{2M}{x^3}(\pi a^2) = \frac{\mu_0 Ma^2}{2x^3}$$

∴ Induced emf in the coil, due to motion of the magnet is

$$e = \frac{-d\phi}{dt} = -\left(\frac{\mu_0 Ma^2}{2}\right)\frac{d}{dt}\left(\frac{1}{x^3}\right)$$

$$= \frac{\mu_0 Ma^2}{2}\left(\frac{3}{x^4}\right)\frac{dx}{dt} = \frac{3}{2}\frac{\mu_0 Ma^2}{x^4}v \quad \left(\because \frac{dx}{dt} = v\right)$$

Therefore, induced current in the coil is

$$i = \frac{e}{R} = \frac{3}{2}\frac{\mu_0 Ma^2}{Rx^4}v$$

Magnetic moment of the coil due to this induced current will be,

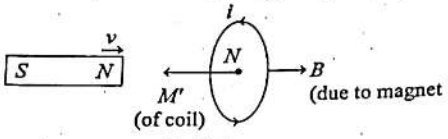
$$M' = iS = \frac{3}{2}\frac{\mu_0 Ma^2}{Rx^4}v(\pi a^2)$$

$$\Rightarrow M' = \frac{3}{2}\frac{\mu_0 \pi Ma^4 v}{Rx^4}$$

Potential energy of M' in B will be

$U = -M'B\cos 180°$

$$U = M'B = \frac{3}{2}\frac{\mu_0 \pi Ma^4 v}{Rx^4}\left(\frac{\mu_0}{2\pi}\cdot\frac{M}{x^3}\right)$$



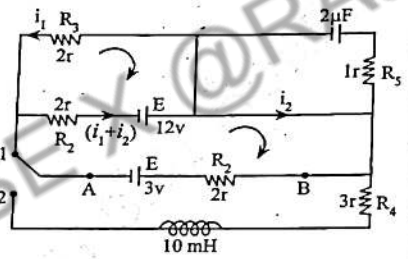
$$U = \frac{3}{4}\frac{\mu_0^2 M^2 a^4 v}{R}\frac{1}{x^7}$$

$$\Rightarrow F = -\frac{dU}{dx} = \frac{21}{4}\frac{\mu_0^2 M^2 a^4 v}{Rx^8}$$

Positive sign of F implies that there will be a repulsion between the magnet and the coil.

60. The capacitor offers infinite resistance to dc in the steady state, therefore the current in the capacitor branch is zero.

Therefore the distribution of current according to Kirchhoff's first law can be applied on the figure when the switch to position 1 is connected.



Now, applying Kirchhoff's second law to the first mesh,

$i_1 \times 2 + (i_1 + i_2) \times 2 = 12$

$4i_1 \times 2i_2 = 12 \Rightarrow 2i_1 + i_2 = 6$ ...(1)

Applying Kirchhoff's second law to the second mesh

$i_2 \times 2 + (i_1 + i_2)2 = 3 \Rightarrow 2i_1 + 4i_2 = 9$ ...(2)

Solving equ(1) and equ (2) we get, $i_1 = 2.5A$ and $i2 = -1A$.

Potential difference between A and B is

$V_B - V_A = V = E_2 - i_2R_2 = 3 - (-1) \times 2 = 5V$

$V_A - V_B = -5V$

Now, Rate of production of heat 'R',

$P = (i_1 + i_2)R_1$

$= (3.5) \times 2 = 24.5$ W

So when switch is put in position 2, then the second equivalent circuit takes form.

Therefore the total resistance of the circuit,

$R = R_2 + R_4 = 2 + 3 = 5\Omega$

$L = 10$ mH $= 10 \times 10^{-3}$ H

In steady state, there is role of inductor L:

So, steady current $i_0 = E/R = \frac{3}{5} = 0.6A$.

The growth of the current in RL circuit is given by $i = i_0\left(1 - e^{-\frac{R}{L}t}\right) \Rightarrow \frac{i}{i_0} = \left(1 - e^{-\frac{R}{L}t}\right)$

Now, given $i = \frac{i_0}{2}$ and $\frac{i}{i_0} = \frac{1}{2}$ after time t.

$$\frac{1}{2} = e^{-\frac{R}{L}t} \Rightarrow \frac{R}{L}t = \log_e(2)$$

$$t = \frac{L}{R}\log_e(2) = \frac{10\times10^{-3}}{5}\log_e(2) = 1.38\times10^{-3}s$$

The current at that instant, $i = \frac{i_0}{2} = 0.3A$

Now the energy stored,

$$U = \frac{1}{2}Li^2 = \frac{1}{2}\times10\times10^{-3}\times(0.3)^2 = 4.5\times10^{-4}J$$

@FAKE_CBSE_@RAJ_EDUNET

23

Alternating Current

Scan for ⊙ Sol.

JEE-Main

Average, Peak and Rms Value

1. A alternating current at any instant is given by $i=\left[6+\sqrt{56}\sin\left(100\pi t+\frac{\pi}{3}\right)\right]A$. The rms value of the current is_____ A. **[04 April, 2024 (Shift-I)]**

2. Match List – I with List – II. **[25 June, 2022 (Shift-I)]**

	List – I		List – II
A.	AC generator	I.	Detects the presence of current in the circuit
B.	Galvanometer	II.	Converts mechanical energy into electrical energy
C.	Transformer	III.	Works on the principle of resonance in AC circuit
D.	Metal detector	IV.	Changes an alternating voltage for smaller or greater value

Choose the correct answer from the options given below:

(a) (A) – (II), (B) – (I), (C) – (IV), (D) – (III)
(b) (A) – (II), (B) – (I), (C) – (III), (D) – (IV)
(c) (A) – (III), (B) – (IV), (C) – (II), (D) – (I)
(d) (A) – (III), (B) – (I), (C) – (II), (D) – (IV)

3. A resistance of 40 Ω is connected to a source of alternating current rated 220 V, 50 Hz. Find the time taken by the current to change from its maximum value to the *rms* value: **[24 June, 2022 (Shift-I)]**

(a) 2.5 ms (b) 1.25 ms (c) 2.5 s (d) 0.25 s

4. The current flowing through an ac circuit is given by $I=5\sin(12\pi t)$ A How long will the current take to reach the peak value staring from zero? **[27 June, 2022 (Shift-I)]**

(a) $\frac{1}{60}$s (b) 60 s (c) $\frac{1}{120}$s (d) $\frac{1}{240}$s

5. A10 Ω resistance is connected across 220 V – 50 Hz AC supply. The time taken by the current to change from its maximum value to the rms value is: **[25 July, 2021 (Shift-II)]**

(a) 2.5 ms (b) 4.5 ms (c) 3.0 ms (d) 1.5 ms

6. An alternating is given by the equation $I=I_1\sin\omega t+I_2\cos\omega t$. Then rms current will be: **[26 Feb, 2021 (Shift-I)]**

(a) $\frac{1}{\sqrt{2}}\left(i_1^2+i_2^2\right)^{\frac{1}{2}}$ (b) $\frac{1}{\sqrt{2}}\left(i_1+i_2\right)^2$
(c) $\frac{1}{\sqrt{2}}\left(i_2+i_2\right)$ (d) $\frac{1}{2}\left(i_1^2+i_2^2\right)^{\frac{1}{2}}$

7. An AC current is given by $I=I_1\sin\omega t+I_2\cos\omega t$. A hot wire ammeter will give a reading: **[17 March, 2021 (Shift-I)]**

(a) $\frac{I_1+I_2}{2\sqrt{2}}$ (b) $\sqrt{\frac{I_1^2+I_2^2}{2}}$ (c) $\frac{I_1+I_2}{\sqrt{2}}$ (d) $\sqrt{\frac{I_1^2-I_2^2}{2}}$

8. The alternating current is given by

$i=\left\{\sqrt{42}\sin\left(\frac{2\pi}{T}t\right)+10\right\}A$

The r.m.s. value of this current is _____ A **[27 Aug, 2021 (Shift-I)]**

9. An alternating voltage $v(t)=220\sin 100\pi t$ volt is applied to a purely resistive load of 50 Ω. The time taken for the current to rise from half of the peak value to the peak value is **[8 April, 2019 (Shift-I)]**

(a) 2.2 ms (b) 5 ms (c) 3.3 ms (d) 7.2 ms

A.C. Across Pure Resistor, Inductor and Capacitor

10. An alternating voltage $V(t)=220\sin 100\pi t$ volt is applied to a purely resistive load of 50 Ω. The time taken for the current to rise from half of the peak value to the peak value is: **[30 Jan, 2024 (Shift-II)]**

(a) 5 ms (b) 3.3 ms (c) 7.2 ms (d) 2.2 ms

11. A capacitor of capacitance 150.0 μF is connected to an alternating source of emf given by $E=36\sin(120\pi t)$ V. The maximum value of current in the circuit is approximately equal to: **[6 April, 2023 (Shift-II)]**

(a) 2A (b) $\frac{1}{\sqrt{2}}A$ (c) $\sqrt{2}A$ (d) $2\sqrt{2}A$

12. An alternating voltage source V = 260 sin (628*t*) is connected across a pure inductor of 5mH. Inductive reactance in the circuit is: **[31 Jan, 2023 (Shift-II)]**

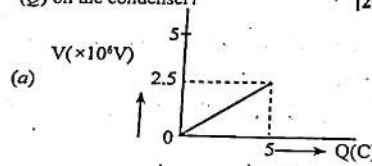
(a) 3.14 Ω (b) 6.28 Ω (c) 0.5 Ω (d) 0.318 Ω

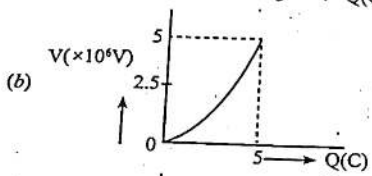
@RAKESHCBSE_X @RAJ_EDUKIT

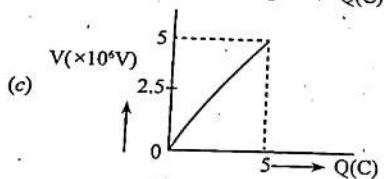
13. If R, X_L and X_C represent resistance, inductive reactance and capacitive reactance. Then which of the following is dimensionless:
[31 Jan, 2023 (Shift-I)]

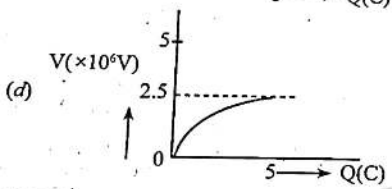
(a) RX_LX_C (b) $\frac{R}{\sqrt{X_LX_C}}$ (c) $\frac{R}{X_LX_C}$ (d) $R\frac{X_L}{X_C}$

14. A condenser of 2μF capacitance is charged steadily from 0 to 5 C. Which of the following graph represents correctly the variation of potential difference (V) across it's plates with respect to the charge (Q) on the condenser? **[25 July, 2022 (Shift-I)]**

(a)


(b)


(c)


(d)


15. If Wattless current flows in the AC circuit, then the circuit is:
[25 June, 2022 (Shift-I)]

(a) Purely Resistive circuit (b) Purely Inductive circuit
(c) LCR series circuit (d) RC series circuit only

16. The rms value of conduction current in a parallel plate capacitor is 6.9 μA. The capacity of this capacitor, if it is connected to 203 V ac supply with an angular frequency of 600 rad/s, will be:
[25 July, 2022 (Shift-I)]

(a) 5 pF (b) 50 pF (c) 100 pF (d) 200 pF

17. An alternating emf $E = 440 \sin 100\pi t$ is applied to a circuit containing an inductance of $\frac{\sqrt{2}}{\pi}H$. If an a.c. ammeter is connected in the circuit, its reading will be: **[29 July, 2022 (Shift-I)]**

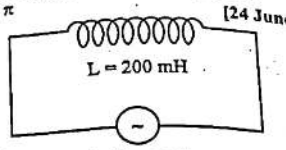
(a) 4.4 A (b) 1.55 A (c) 2.2 A (d) 3.11 A

18. The equation of current in a purely inductive circuit is $5\sin(49\pi t - 30°)$. If the inductance is 30 mH then the equation for the voltage across the inductor, will be:

$\left\{\text{Let } \pi = \frac{22}{7}\right\}$ **[28 July, 2022 (Shift-I)]**

(a) $1.47\sin(49\pi t - 30°)$ (b) $1.47\sin(49\pi t + 60°)$
(c) $23.1\sin(49\pi t - 30°)$ (d) $23.1\sin(49\pi t + 60°)$

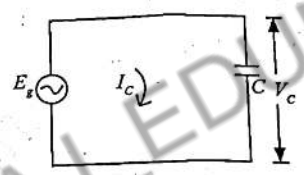
19. As shown in the figure an inductor of inductance 200 mH is connected to an AC source of emf 220 V and frequency 50 Hz. The instantaneous voltage of the source is 0 V when the peak value of current is a $\frac{\sqrt{a}}{\pi}A$. The value of a is_____.
[24 June, 2022 (Shift-I)]

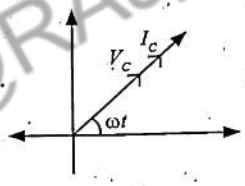


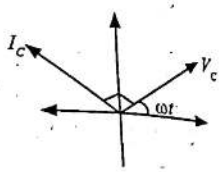
20. What happens to the inductive reactance and the current in a purely inductive circuit if the frequency is halved?
[17 March, 2021 (Shift-II)]

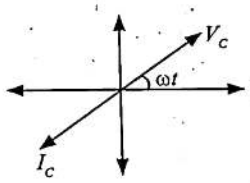
(a) Both, inducting reactance and current will be doubled.
(b) Inductive reactance will be doubled and current will be halved.
(c) Both, inductive reactance and current will be halved.
(d) Inductive reactance will be halved and current will be doubled.

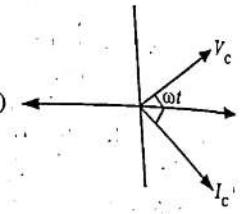
21. In a circuit consisting of a capacitance and a generator with alternating emf $E_g = E_{g_0}\sin\omega t$, V_C and I_C are the voltage and current. Correct phase diagram for such circuit is: **[22 July, 2021 (Shift-II)]**



(a)


(b)


(c)


(d)


22. An AC source rated 220V, 50Hz is connected to a resistor. The time taken by the current to change from its maximum to the rms value is **[18 March, 2021 (Shift-I)]**

(a) 2.5 ms (b) 25 ms (c) 2.5 s (d) 0.25 ms

23. A circuit connected to an ac source of emf $e = e_0\sin(100t)$ with t in seconds, gives a phase difference of $\frac{\pi}{4}$ between the emf e and current i. Which of the following circuits will exhibit this?
[8 April, 2019 (Shift-II)]

(a) RC circuit with $R = 1\ k\Omega$ and $C = 1\mu F$.
(b) RL circuit with $R = 1\ k\Omega$ and $L = 1mH$.
(c) RL circuit with $R = 1\ k\Omega$ and $L = 10\ mH$.
(d) RC circuit with $R = 1\ k\Omega$ and $C = 10\ \mu F$.

@PACE_CASE_X @RAJ_EDUNEET

...nce 200 mH is ...requency 50 Hz. The ... V when the peak value of ... is ____.

[24 June, 2022 (Shift-I)]

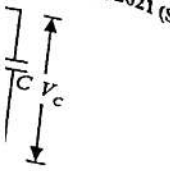
...H

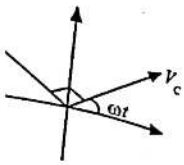
...tance and the current in a purely ... halved?

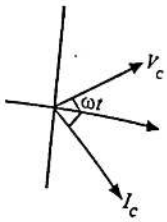
[17 March, 2021 (Shift-II)]

...urrent will be doubled.
...led and current will be halved.
...rrent will be halved.
...d and current will be doubled.

...tance and a generator with ... are the voltage and current ... is:[22 July, 2021 (Shift-II)]







...ed to a resistor. The ...naximum to the rms ...rch, 2021 (Shift-I)]

(d) 0.25 ms

... = $e_0 \sin(100t)$ with t ...veen the emf e and ...

...chibit this? ...l, 2019 (Shift-II)]

A.C. Across L-R, L-C and R-C

24. A coil of negligible resistance is connected in series with 90 Ω resistor across 120 V, 60 Hz supply. A voltmeter reads 36 V across resistance. Inductance of the coil is: [08 April, 2024 (Shift-II)]
(a) 0.76 H (b) 2.86 H (c) 0.286 H (d) 0.91 H

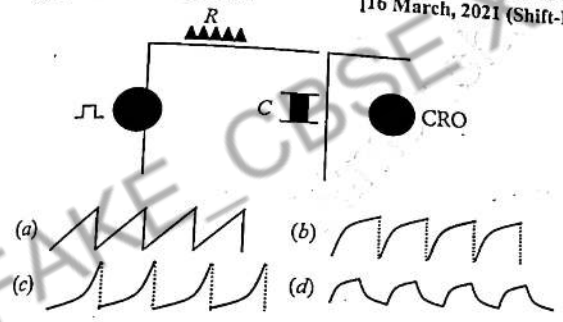
25. An alternating emf $E = 100\sqrt{2}\sin 100t$ volt is applied to a capacitor of 2 μF, the rms value of current in the circuit is ..... mA. [08 April, 2024 (Shift-II)]

26. A bulb and a capacitor are connected in series across an ac supply. A dielectric is then placed between the plates of the capacitor. The glow of the bulb: [09 April, 2024 (Shift-I)]
(a) increases (b) remains same
(c) becomes zero (d) decreases

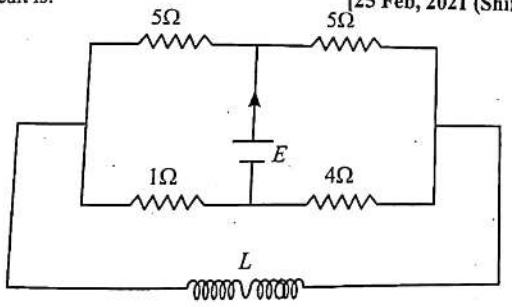
27. To light, a 50 W, 100 V lamp is connected, in series with a capacitor of a capacitance $\frac{50}{\pi\sqrt{x}}\mu F$, with 200V, 50Hz AC source. The value of x will be _____. [27 July, 2022 (Shift-I)]

28. A circuit element X when connected to an a.c. supply of peak voltage 100 V gives a peak current of 5 A which is in phase with the voltage. A second element Y when connected to the same a.c. supply also gives the same value of peak current which lags behind the voltage by $\frac{\pi}{2}$. If X and Y are connected in series to the same supply, what will be the rms value of the current in ampere? [29 July, 2022 (Shift-II)]
(a) $\frac{10}{\sqrt{2}}$ (b) $\frac{5}{\sqrt{2}}$ (c) $5\sqrt{2}$ (d) $\frac{5}{2}$

29. An RC circuit as shown in the figure is driven by a AC source generating a square wave. The output wave pattern monitored by CRO would look close to: [16 March, 2021 (Shift-I)]



30. The current (i) at time $t = 0$ and $t = \infty$ respectively for the given circuit is: [25 Feb, 2021 (Shift-I)]



(a) $\frac{5E}{18}, \frac{18E}{55}$ (b) $\frac{18E}{55}, \frac{5E}{18}$
(c) $\frac{5E}{18}, \frac{10E}{33}$ (d) $\frac{10E}{33}, \frac{5E}{18}$

31. An ac circuit has an inductor and a resistor of resistance R in series, such that $X_L = 3R$. Now, a capacitor is added in series such that $X_C = 2R$. The ratio of new power factor with the old power factor of the circuit is $\sqrt{5} : x$ The value of x is _____. [27 Aug, 2021 (Shift-II)]

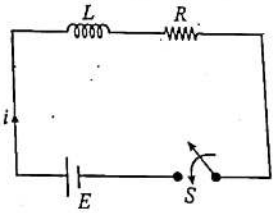
32. A 0.07 H inductor and a 12 Ω resistor are connected in series to a 220 V, 50 Hz ac source. The approximate current in the circuit and the phase angle between current and source voltage are respectively. [Take π as 22/7] [27 July, 2021 (Shift-I)]
(a) 88 A and $\tan^{-1}\left(\frac{11}{6}\right)$ (b) 8.8 A and $\tan^{-1}\left(\frac{11}{6}\right)$
(c) 0.88 A and $\tan^{-1}\left(\frac{11}{6}\right)$ (d) 8.8 A and $\tan^{-1}\left(\frac{11}{6}\right)$

33. In LC circuit the inductance L = 40 mH and capacitance C = 100 μF. If a voltage $V(t) = 10\sin(314t)$ is applied to the circuit, to the current in the circuit is given as [9 Jan, 2020 (Shift-II)]
(a) 0.52 cos (314 t) (b) 10 cos (314 t)
(c) 5.2 cos (314 t) (d) 0.52 sin (314 t)

34. A series L-R circuit is connected to a battery of emf V. If the circuit is switched on at $t = 0$, then the time at which the energy stored in the inductor reaches $\left(\frac{1}{n}\right)$ times of its maximum value, is [4 Sep, 2020 (Shift-II)]
(a) $\frac{L}{R}\ln\left(\frac{\sqrt{n}+1}{\sqrt{n}-1}\right)$ (b) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}-1}\right)$
(c) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}+1}\right)$ (d) $\frac{L}{R}\ln\left(\frac{\sqrt{n}-1}{\sqrt{n}}\right)$

35. In the figure shown, a circuit contains two identical resistors with resistance $R = 5\ \Omega$ and an inductance with $L = 2$ mH. An ideal battery of 15 V is connected in the circuit. What will be the current (after the switch is closed) _____ A. [12 Jan, 2019 (Shift-I)]

36. Consider the LR circuit shown in the figure. If the switch S is closed at $t = 0$ then the amount of charge that passes through the battery between $t = 0$ and $t = \frac{L}{R}$ is [12 April, 2019 (Shift-II)]



(a) $\frac{EL}{7.3R^2}$ (b) $\frac{EL}{2.7R^2}$ (c) $\frac{7.3EL}{R^2}$ (d) $\frac{2.7EL}{R^2}$

@FAKE_CBSE_@RAJEDUNET

LCR Series Circuit

37. A series *LCR* circuit with $L = \frac{100}{\pi}$ mH, $C = \frac{10^{-3}}{\pi}$ F and R = 10Ω, is connected across an ac source of 220V, 50Hz supply. The power factor of the circuit would be _____. **[27 Jan, 2024 (Shift-II)]**

38. In series LCR circuit, the capacitance is changed from C to 4C. To keep the resonance frequency unchanged, the new inductance should be: **[1 Feb, 2024 (Shift-I)]**

(a) reduced by $\frac{1}{4}$ L (b) increased by 2 L

(c) reduced by $\frac{3}{4}$ L (d) increased to 4 L

39. In an ac circuit, the instantaneous current is zero, when the instantaneous voltage is maximum. In this case, the source may be connected to:

A. pure inductor.

B. pure capacitor.

C. pure resistor.

D. combination of an inductor and capacitor.

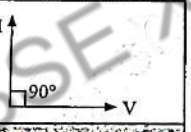
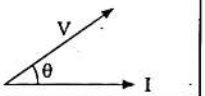
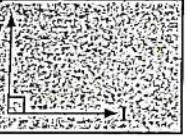
Choose the correct answer from the options given below:

[04 April, 2024 (Shift-I)]

(a) A, B and C only (b) B, C and D only

(c) A and B only (d) A, B and D only

40. Match List I with List II

	List-I		List-II
A.	Purely capacitive circuit	I.	
B.	Purely inductive circuit	II.	
C.	LCR series at resonance	III.	
D.	LCR series circuit	IV.	

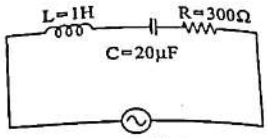
Choose the correct answer from the options given below:

[04 April, 2024 (Shift-II)]

(a) A-I, B-IV, C-III, D-II (b) A-IV, B-I, C-III, D-II

(c) A-IV, B-I, C-II, D-III (d) A-I, B-IV, C-II, D-III

41. An ac source is connected in given series LCR circuit. The rms potential difference across the capacitor of 20 μF is ..... V. **[05 April, 2024 (Shift-I)]**



$V = 50\sqrt{2}\sin 100t$ volt

42. A series LCR circuit is subjected to an AC signal of 200 V, 50 Hz. If the voltage across the inductor (L = 10 mH) is 31.4 V, then the current in this circuit is _____: **[05 April, 2024 (Shift-II)]**

(a) 68 A (b) 63 A (c) 10 A (d) 10 mA

43. Given below are two statements :

Statement I: In an LCR series circuit, current is maximum at resonance.

Statement II: Current in a purely resistive circuit can never be less than that in a series LCR circuit when connected to same voltage source.

In the light of the above statements, choose the correct from the options given below: **[06 April, 2024 (Shift-I)]**

(a) Statement I is true but Statement II is false

(b) Statement I is false but Statement II is true

(c) Both Statement I and Statement II are true

(d) Both Statement I and Statement II are false

44. For a given series LCR circuit it is found that maximum current is drawn when value of variable capacitance is 2.5 nF. If resistance of 200Ω and 100 mH inductor is being used in the given circuit. The frequency of ac source is _____ $\times 10^3$ Hz. (given $\pi^2 = 10$) **[06 April, 2024 (Shift-II)]**

45. A *LCR* circuit is at resonance for a capacitor C, inductance L and resistance R. Now the value of resistance is halved keeping all other parameters same. The current amplitude at resonance will be now: **[08 April, 2024 (Shift-I)]**

(a) Zero (b) double (c) same (d) halved

46. A capacitor of reactance $4\sqrt{3}\,\Omega$ and a resistor of resistance 4Ω are connected in series with an ac source of peak value $8\sqrt{2}$ V. The power dissipation in the circuit is .....W. **[09 April, 2024 (Shift-II)]**

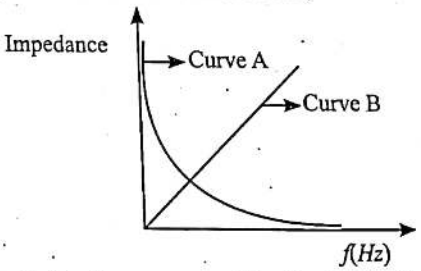
47. As per the given graph choose the correct representation for curve A and curve B. **[11 April, 2023 (Shift-I)]**

{Where X_C = reactance of pure capacitive circuit connected with A.C. source

X_L = reactance of pure inductive circuit connected with A.C. source

R = impedance of pure resistive circuit connected with A.C. source

Z = Impedance of the LCR series circuit}



(a) $A = X_C, B = R$ (b) $A = X_L, B = Z$

(c) $A = X_C, B = X_L$ (d) $A = X_L, B = R$

@RAJ_CBSE_NET

sin 100t volt

an AC signal of 200 V, 50 Hz
L = 10 mH) is 31.4 V, then the
10 A [05 April, 2024 (Shift-II)]
(d) 10 mA

rcuit, current is maximum a

istive circuit can never be less
en connected to same voltage

choose the correct from the
[06 April, 2024 (Shift-I)]
II is false
II is true
are true
are false

d that maximum current is
e is 2.5 nF. If resistance of
d in the given circuit. The
z.
06 April, 2024 (Shift-II)]
itor C, inductance L and
s halved keeping all other
t resonance will be now:
08 April, 2024 (Shift-I)]
(d) halved

stor of resistance 4Ω are

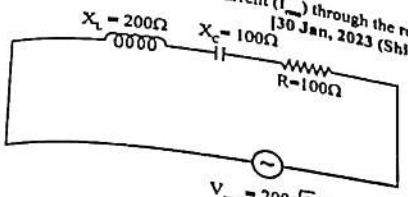
eak value $8\sqrt{2}$ V. The
.....W.
April, 2024 (Shift-II)]
presentation for curve
April, 2023 (Shift-I)]
ircuit connected with

cted with A.C. source
cted with A.C. source

3

Z
R

48. In the given circuit, rms value of current (I_{rms}) through the resistor R is: [30 Jan, 2023 (Shift-II)]



(a) 2A (b) 1/2 A (c) 20A (d) $2\sqrt{2}$ A

49. In a series LR circuit with $X_L = R$, power factor is P_1. If a capacitor of capacitance C with $X_C = X_L$ is added to the circuit the power factor becomes P_2. The ratio of P_1 to P_2 will be: [30 Jan, 2023 (Shift-I)]

(a) 1 : 3 (b) $1:\sqrt{2}$ (c) 1 : 1 (d) 1 : 2

50. Given below are two statements:

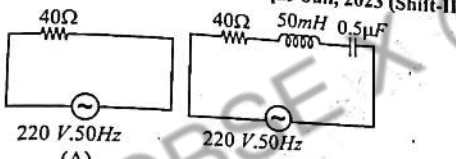
Statement-I : Maximum power is dissipated in a circuit containing an inductor, a capacitor and a resistor connected in series with an AC source, when resonance occurs

Statement-II : Maximum power is dissipated in a circuit containing pure resistor due to zero phase difference between current and voltage.

In the light of the above statements, choose the correct answer from the options given below : [10 April, 2023 (Shift-I)]

(a) Statement-I is false but Statement-II is true
(b) Statement-I is true but Statement-II is false
(c) Both Statement-I and Statement-II are true
(d) Both Statement-I and Statement-II are false

51. For the given figures, choose the correct options: [29 Jan, 2023 (Shift-II)]



(a) The rms current in circuit (B) can never be larger than that in (A)
(b) The rms current in figure (A) is always equal to that in figure (B)
(c) The rms current in circuit (B) can be larger than that in (A)
(d) At resonance, current in (B) is less than that in (A)

52. Given below are two statements:

Statements-I : When the frequency of an a.c. source in a series LCR circuit increases, the current in the circuit first increases, attains a maximum value and then decreases.

Statements-II : In a series LCR circuit, the value of power factor at resonance is one.

In the light of given statements, choose the most appropriate answer from the options given below: [12 April, 2023 (Shift-I)]

(a) Statement-I is incorrect but Statement-II is true.
(b) Both Statement-I and Statement-II are false.
(c) Statement-I is correct but Statement-II is false.
(d) Both Statement-I and Statement-II are true.

53. A series LCR circuit consists of R = 80Ω, X_L = 100Ω, and X_C = 40Ω. The input voltage is 2500 cos(100 πt)V. The amplitude of current, in the circuit, is _____ A. [31 Jan, 2023 (Shift-II)]

54. An inductor of inductance 2μH is connected in series with a resistance, a variable capacitor and an AC source of frequency 7 MHz. The value of capacitance for which maximum current is drawn into the circuit is $\frac{1}{x}F$, where the value of x is_____.

(Use $\pi = \frac{22}{7}$) [29 Jan, 2023 (Shift-II)]

55. An inductor of 0.5 mH, a capacitor of 20μF and a resistance of 20Ω are connected in series with a 220V ac source. If the current is in phase with the emf, the amplitude of current of the circuit is $\sqrt{x}A$. The value of x is_____. [31 Jan, 2023 (Shift-I)]

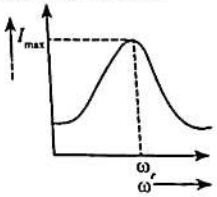
56. An LCR series circuit of capacitance 62.5nF and resistance of 50Ω is connected to an A.C. source of frequency 2.0kHz. For maximum value of amplitude of current in circuit, the value of inductance is _____ mH.
(take $\pi^2 = 10$) [25 Jan, 2023 (Shift-I)]

57. A series LCR circuit is connected to an AC source of 220 V, 50 Hz. The circuit contains a resistance of R = 80Ω, an inductor of inductive reactance X_L = 70Ω and a capacitor of capacitive reactance X_C = 130Ω. The power factor of the circuit is $\frac{x}{10}$. The value of x is _____. [25 Jan, 2023 (Shift-II)]

58. A series LCR circuit is connected to an ac source of 220 V, 50 Hz. The circuit contain a resistance R = 100Ω and an inductor of inductive reactance X_L = 79.6Ω. The capacitance of the capacitor needed to maximize the average rate at which energy is supplied will be _____ μF. [1 Feb, 2023 (Shift-I)]

59. For a series LCR circuit, I vs ω curve is shown:

A. To the left of ω_r, the circuit is mainly capacitive.
B. To the left of ω_r, the circuit is mainly inductive.
C. At ω_r, impedance of the circuit is equal to the resistance of the circuit.
D. At ω_r, impedance of the circuit is 0 .



Choose the most appropriate answer from the options given below: [29 June, 2022 (Shift-I)]

(a) (A) and (D) only (b) (B) and (D) only
(c) (A) and (C) only (d) (B) and (C) only

60. A sinusoidal voltage $V(t) = 210 \sin 3000t$ volt is applied to a series LCR circuit in which L = 10mH, C = 25μF and R = 100Ω. The phase difference (ϕ) between the applied voltage and resultant current will be: [25 June, 2022 (Shift-II)]

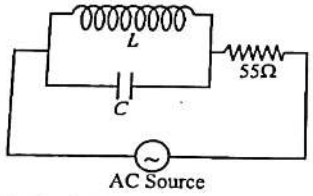
(a) $\tan^{-1}(0.17)$ (b) $\tan^{-1}(9.46)$
(c) $\tan^{-1}(0.30)$ (d) $\tan^{-1}(13.33)$

@FREE_CBSE_@FILED_IIT

61. To increase the resonant frequency in series LCR circuit,
[25 July, 2022 (Shift-I)]
(a) Source frequency should be increased.
(b) Another resistance should be added in series with the first resistance.
(c) Another capacitor should be added in series with the first capacitor.
(d) The source frequency should be decreased.

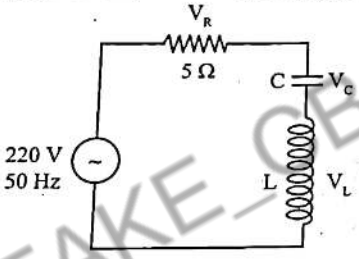
62. If L, C and R are the self inductance, capacitance and resistance respectively, which of the following does not have the dimension of time?
[27 June, 2022 (Shift-II)]
(a) RC (b) $\frac{L}{R}$ (c) $\sqrt{LC}$ (d) $\frac{L}{C}$

63. A 110 V, 50 Hz, AC source is connected in the circuit (as shown in figure). The current through the resistance 55 Ω, at resonance in the circuit, will be _____ A. **[26 June, 2022 (Shift-I)]**



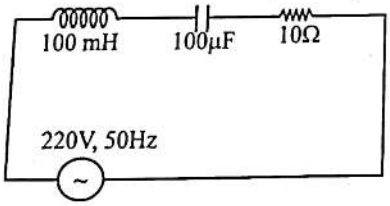
64. A series LCR circuit has $L = 0.01H$, $R = 10\Omega$ and C = 1μF and it is connected to ac voltage of amplitude (V_m) 50 V. At frequency 60% lower than resonant frequency the amplitude of current will be approximately:
[27 July, 2022 (Shift-II)]
(a) 466 mA (b) 312 mA (c) 238 mA (d) 196 mA

65. In the given circuit, the magnitude of V_L and V_C are twice that of V_R. Given that $f = 50$ Hz, the inductance of the coil is $1/K\pi$ mH. The value of K is _____.
[28 June, 2022 (Shift-II)]



66. The frequencies at which the current amplitude in an LCR series circuit becomes $\frac{1}{\sqrt{2}}$ times its maximum value, are 212 rad s^{-1} and 232 rad s^{-1}. The value of resistance in the circuit is $R = 5\Omega$. The self inductance in the circuit is _____ mH. **[28 July, 2022 (Shift-I)]**

67. In a series LCR circuit, the inductance, capacitance and resistance are $L = 100$ mH, $C = 100\mu F$ and $R = 10\Omega$ respectively. They are connected to an AC source of voltage 220 V and frequency of 50 Hz. The approximate value of current in the circuit will be _____ A.
[25 June, 2022 (Shift-II)]

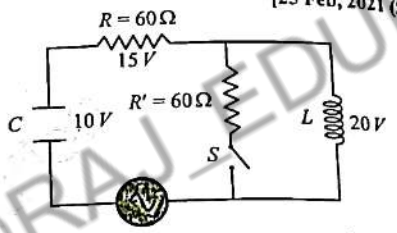


68. A telegraph line of length 100 km has a capacity of 0.01 μF/km and it carries an alternating current at 0.5 kilo cycle per second. If minimum impedance is required, then the value of the inductance that need to be introduced in series is _____ mH. (if $\pi = \sqrt{10}$)
[28 June, 2022 (Shift-I)]

69. An inductor of 0.5 mH, a capacitor of 200 μF and a resistor of 2 Ω are connected in series with a 220 V ac source. If the current is in phase with the emf, the frequency of ac source will be _____, 10^2 Hz.
[29 June, 2022 (Shift-II)]

70. For a series LCR circuit with $R = 100\Omega$, $L = 0.5$mH and $C = 0.1$pF connected across 220V – 50Hz AC supply, the phase angle between current and supplied voltage and the nature of the circuit is:
[20 July, 2021 (Shift-II)]
(a) ≈ 90°, predominantly inductive circuit
(b) 0°, resonance circuit
(c) ≈ 90°, predominantly capacitive circuit
(d) 0°, resistive circuit

71. The angular frequency of alternating current in a LCR circuit is 1(s) rad/s. The components connected are shown in the figure. Find the value of inductance of the coil and capacity of condenser.
[25 Feb, 2021 (Shift-I)]



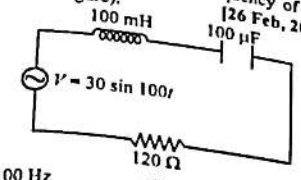
(a) 0.8 H and 150 μF (b) 1.33 H and 250μ F
(c) 0.8 H and 250 μF (d) 1.33 H and 150 μF

72. Match List-I with List-II **[17 March, 2021 (Shift-II)]**
List-I
(A) Phase difference between current and voltage in a purely resistive AC circuit
(B) Phase difference between current and voltage in a pure inductive AC circuit
(C) Phase difference between current and voltage in a pure capacitive AC circuit
(D) Phase difference between current and voltage in an LCR series circuit
List-II
(i) $\frac{\pi}{2}$; current leads voltage (ii) Zero
(iii) $\frac{\pi}{2}$; current lags voltage (iv) $\tan^{-1}\left(\frac{X_C - X_L}{R}\right)$
Choose the most appropriate answer from the options given below:
(a) (A) - (ii), (B) - (iii), (C) - (iv), (D) - (i)
(b) (A) - (ii), (B) - (iii), (C) - (i), (D) - (iv)
(c) (A) - (i), (B) - (iii), (C) - (iv), (D) - (ii)
(d) (A) - (ii), (B) - (iv), (C) - (iii), (D) - (i)

73. In an ac circuit, an inductor, a capacitor and a resistor are connected in series with $X_L = R = X_C$. Impedance of this circuit is:
[31 Aug, 2021 (Shift-I)]
(a) $2R^2$ (b) Zero (c) $R\sqrt{2}$ (d) R

@TAKE_CBSE_X@RAJ_EDUNET

74. Find the peak current and resonant frequency of the following circuit (as shown in figure). [26 Feb, 2021 (Shift-II)]



(a) 2 A and 100 Hz (b) 2 A and 50 Hz
(c) 0.2 A and 50 Hz (d) 0.2 A and 100 Hz

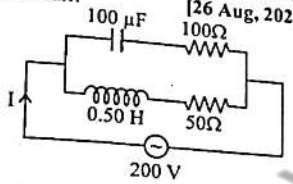
75. An LCR circuit contains resistance of 110Ω and a supply of 220 V at 300 rad/s angular frequency. If only capacitance is removed from the circuit, current lags behind the voltage by 45°. If on the other hand, only inductor is removed the current leads by 45° with the applied voltage. The rms current flowing in the circuit will be: [25 Feb, 2021 (Shift-II)]

(a) 1 A (b) 2 A (c) 1.5 A (d) 2.5 A

76. A series *LCR* circuit driven by 300 *V* at a frequency of 50 Hz contains a resistance $R = 3k\Omega$, an inductor of inductive reactances $X_L = 250\pi\Omega$ and an unknown capacitor. The value of capacitance to maximize the average power should be : (Take $\pi^2 = 10$) [26 Aug, 2021 (Shift-I)]

(a) $400\mu F$ (b) $4\mu F$ (c) $40\mu F$ (d) $25\mu F$

77. In the given circuit the AC source has $\omega = 100$ rad s^{-1}. Considering the inductor and capacitor to be ideal, what will be the current I flowing through the circuit? [26 Aug, 2021 (Shift-II)]



(a) 5.9 A (b) 4.24 A (c) 6 A (d) 0.94 A

78. Match List-I with List-II: [22 July, 2021 (Shift-II)]

List – I		List – II	
A.	$\omega L > \frac{1}{\omega C}$	I.	Current is in phase with emf
B.	$\omega L = \frac{1}{\omega C}$	II.	Current lags behind the applied emf
C.	$\omega L < \frac{1}{\omega C}$	III.	Maximum current occurs
D.	Resonant frequency	IV.	Current leads the emf

Choose the correct answer from the options given below:

(a) (A) – (IV); (B) – (III); (C) – (II); (D) – (I)
(b) (A) – (II); (B) – (I); (C) – (IV); (D) – (III)
(c) (A) – (III); (B) – (I); (C) – (IV); (D) – (II)
(d) (A) – (II); (B) – (I); (C) – (III); (D) – (IV)

79. A 100Ω resistance, a 0.1 μF capacitor and an inductor are connected in series across a 250 V supply at variable frequency. Calculate the value if inductance of inductor at which resonance will occur. Given that the resonant frequency is 60 Hz. [27 July, 2021 (Shift-II)]

(a) 7.03×10^{-1} H (b) 70.3 H
(c) 70.3 mH (d) 0.70 H

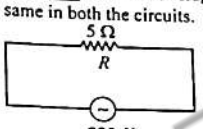
80. A resonance circuit having inductance and resistance 2×10^{-4} H and 6.28 Ω respectively oscillates at 10 MHz frequency. The value of quality factor of this resonator is _____. [$\pi = 3.14$] [24 Feb, 2021 (Shift-I)]

81. An In a series LCR circuit, the inductive reactance (X_L) is 10Ω, and the capacitive reactance (X_C) is 4Ω. The resistance (R) in the circuit is 6Ω. The power factor of the circuit is: [18 March, 2021 (Shift-II)]

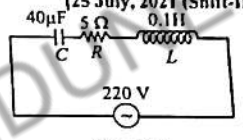
(a) $\frac{1}{2}$ (b) $\frac{\sqrt{3}}{2}$ (c) $\frac{1}{\sqrt{2}}$ (d) $\frac{1}{2\sqrt{2}}$

82. A series LCR circuit of $R = 5\Omega$, $L = 20$mH and $C = 0.5\mu F$ is connected across an *AC* supply of 250V, having variable frequency. The power dissipated at resonance condition is _____ $\times 10^2$ W. [20 July, 2021 (Shift-II)]

83. Two circuits are shown in the figure (a) & (b). At a frequency of _____ rad /s the average power dissipated in one cycle will be same in both the circuits. [25 July, 2021 (Shift-II)]



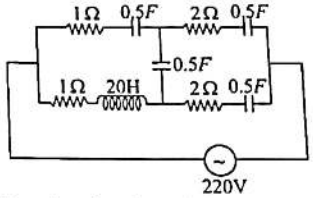
Figure(a)



Figure(b)

84. In a series LCR resonant circuit, the quality factor is measured as 100 . If the inductance is increased by two fold and resistance is decreased by two fold, then the quality factor after this change will be _____. [26 Feb, 2021 (Shift-I)]

85. At very high frequencies, the effective impedance of the given circuit will be _____ Ω. [31 Aug, 2021 (Shift-II)]



86. In an LCR series circuit, an inductor 30 mH and a resistor 1 Ω are connected to an AC source of angular frequency 300 rad/s. The value of capacitance for which, the current leads the voltage by 45° is $\frac{1}{x} \times 10^{-3}$ F. Then the value of x is _____. [20 July, 2021 (Shift-I)]

87. An AC circuit has R = 100Ω, C = μF and L = 80 mH, connected in series. The quality factor of the circuit is: [06 Sep., 2020 (Shift-I)]

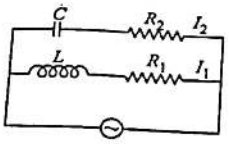
(a) 2 (b) 0.5 (c) 20 (d) 400

88. A LCR circuit behaves like a damped harmonic oscillator. Comparing it with a physical spring-mass damped oscillator having damping constant '*b*', the connect equivalence would be: [07 Jan, 2020 (Shift-I)]

(a) $L \leftrightarrow \frac{1}{b}, C \leftrightarrow \frac{1}{m}, R \leftrightarrow \frac{1}{k}$ (b) $L \leftrightarrow k, C \leftrightarrow b, R \leftrightarrow m$
(c) $L \leftrightarrow m, C \leftrightarrow \frac{1}{k}, R \leftrightarrow b$ (d) $L \leftrightarrow m, C \leftrightarrow k, R \leftrightarrow b$

@FREE OF EX @RL EDUCATION

89.



In the above circuit, $C = \frac{\sqrt{3}}{2}\mu F$, $R_2 = 20\Omega$, $L = \frac{\sqrt{3}}{10}$ H and $R_1 = 10\Omega$. Current in L-R_1 path is I_1 and C-R_2 path is I_2. The voltage of A.C. source is given by $V = 200\sqrt{2}\sin(100t)$ volts. The phase difference between I_1 and I_2 is: **[12 Jan, 2019 (Shift-II)]**

(a) 60° (b) 30° (c) 90° (d) 0°

Power in an AC Circuit

90. In an a.c. circuit, voltage and current are given by: **[29 Jan, 2024 (Shift-II)]**

$V = 100\sin(100\,t)$ V and

$I = 100\sin(100\,t + \frac{\pi}{3})$ mA respectively.

The average power dissipated in one cycle is:

(a) 5 W (b) 10 W (c) 2.5 W (d) 25 W

91. A series L,R circuit connected with an ac source $E = (25\sin 1000\,t)$ V has a power factor of $\frac{1}{\sqrt{2}}$. If the source of emf is changed to $E = (20\sin 2000\,t)$ V, the new power factor of the circuit will be: **[30 Jan, 2024 (Shift-I)]**

(a) $\frac{1}{\sqrt{2}}$ (b) $\frac{1}{\sqrt{3}}$ (c) $\frac{1}{\sqrt{5}}$ (d) $\frac{1}{\sqrt{7}}$

92. An AC voltage $V = 20\sin 200\pi t$ is applied to a series LCR circuit which drives a current $I = 10\sin\left(200\pi t + \frac{\pi}{3}\right)$. The average power dissipated is: **[31 Jan, 2024 (Shift-II)]**

(a) 21.6 W (b) 200 W (c) 173.2 W (d) 50 W

93. When a dc voltage of 100V is applied to an inductor, a dc current of 5A flows through it. When an ac voltage of 200V peak value is connected to inductor, its inductive reactance is found to be $20\sqrt{3}\,\Omega$. The power dissipated in the circuit is _____W. **[06 April, 2024 (Shift-I)]**

94. **Statement–I:** The reactance of an ac circuit is zero. It is possible that the circuit contains a capacitor and an inductor.

Statement–II: In ac circuit, the average power delivered by the source never becomes zero.

In the light of the above statements, choose the correct answer from the options given below **[24 June, 2022 (Shift-II)]**

(a) Both Statement-I and Statement-II are true

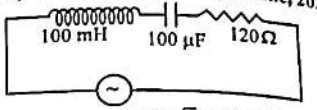
(b) Both Statement-I and Statement-II are false

(c) Statement-I is true but Statement-II is false

(d) Statement-I is false but Statement-II is true

95. To light, a 50 W, 100 V lamp is connected, in series with a capacitor of a capacitance $\frac{50}{\pi\sqrt{x}}\mu F$, with 200V, 50Hz AC source. The value of x will be _____. **[27 July, 2022 (Shift-I)]**

96. An AC source is connected to an inductance of 100 mH, a capacitance of 100 μF and a resistance of 120Ω as shown in figure. The time in which the resistance having a thermal capacity 2 J/°C will get heated by 16°C is _____s. **[28 June, 2022 (Shift-I)]**

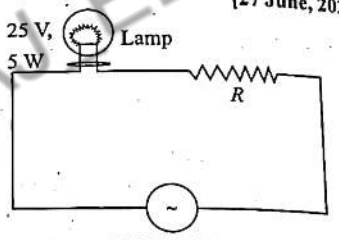


$V = 20\sqrt{2}\sin(100t)$

97. A direct current of 4A and an alternating current of peak value 4A passes through 3 Ω and 2 Ω resistors respectively. Find the ratio of heat generated in two resistance in same interval of time. **[27 July, 2022 (Shift-I)]**

(a) 3 : 2 (b) 3 : 1 (c) 3 : 4 (d) 4 : 3

98. A 220 V, 50 Hz AC source is connected to a 25 V, 5 W lamp and an additional resistance R in series (as shown in figure) to run the lamp at its peak brightness, then the value of R (in ohm) will be _____. **[27 June, 2022 (Shift-I)]**



220 V, 50 Hz

99. A series LCR circuit is designed to resonate at an angular frequency $\omega_0 = 10^5$ rad/s. The circuit draws 16 W power from 120 V source at resonance. The value of resistance 'R' in the circuit is _____Ω **[24 Feb, 2021 (Shift-II)]**

100. A sinusoidal voltage of peak value 250V is applied to a series LCR circuit, in which $R = 8\Omega$, $L = 24$ mH and $C = 60\mu F$. The value of power dissipated at resonant condition is 'x' kW. The value of x to the nearest integer is _____. **[16 March, 2021 (Shift-I)]**

101. An electrical power line, having a total resistance of 2Ω, delivers 1k W at 220 V. The efficiency of the transmission line is approximately: **[05 Sep, 2020 (Shift-I)]**

(a) 96% (b) 72% (c) 91% (d) 85%

102. A 750Hz, 20 V (rms) source is connected to a resistance of 100 Ω, an inductance of 0.1803 H and a capacitance of 10 μF all in series. The time in which the resistance (heat capacity 2 J/°C) will get heated by 10°C. (Assume no loss of heat to the surroudings) is close to **[03 Sep, 2020 (Shift-I)]**

(a) 348 s (b) 418 s (c) 245 s (d) 365 s

103. A series AC circuit containing an inductor (20 mH), a capacitor (120 μF) and a resistor (60 Ω) is driven by an AC source of 24 V/50 Hz. The energy dissipated in the circuit in 60 s is: **[9 Jan, 2019 (Shift-II)]**

(a) 5.65×10^2 J (b) 2.26×10^3 J

(c) 5.17×10^2 J (d) 3.39×10^3 J

@FAKE_CBSE_X @RAJEEB_NIT

L-C Oscillator

104. In an LC oscillator, if the values of inductance and capacitance become twice and eight times, respectively, then the resonant frequency of the oscillator becomes x times its initial resonant frequency ω_0. The value of x is: [25 Jan, 2023 (Shift-I)]
(a) 1/4 (b) 16 (c) 1/16 (d) 4

105. Given below are two statements:
Statement-I : An AC circuit undergoes electrical resonance if it contains either a capacitor or an inductor.
Statement-II : An AC circuit containing a pure capacitor or a pure inductor consumes high power due to its non-zero power factor. In the light of above statements, choose the correct answer from the options given below : [13 April, 2023 (Shift-II)]
(a) Both Statement-I and Statement-II are false
(b) Statement-I is true but Statement-II is false
(c) Both Statement-I and Statement-II are true
(d) Statement-I is false but Statement-II is true

106. An oscillating LC circuit consists of a 75 mH inductor and a 1.2 μF capacitor. If the maximum charge to the capacitor is 2.7 μC. The maximum current in the circuit will be _____ mA. [08 April, 2023 (Shift-I)]

107. When you walk through a metal detector carrying a metal object in your pocket, it raises an alarm. This phenomenon works on: [25 July, 2022 (Shift-II)]
(a) Electromagnetic induction
(b) Resonance in ac circuits
(c) Mutual induction in ac circuits
(d) Interference of electromagnetic waves

108. A capacitor of capacitance 500μF is charged completely using a dc supply of 100 V. It is now connected to an inductor of inductance 50 mH to form an LC circuit. The maximum current in LC circuit will be _____ A. [29 July, 2022 (Shift-II)]

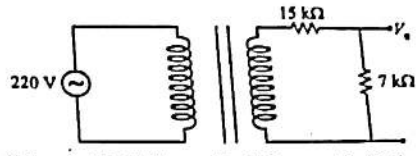
109. Consider an LC circuit with inductance $L = 0.1\ H$ and capacitance $C = 10^{-3}\ F$, kept on a plane. The area of the circuit is 1 m². It is placed in a constant magnetic field of strength B_0 which is perpendicular to the plane of the circuit. At time $t = 0$, the magnetic field strength starts increasing linearly as $B = B_0 + \beta t$ with $\beta = 0.04 Ts^{-1}$. The maximum magnitude of the current in the circuit is _____ mA. [JEE Adv, 2022]

110. In a series LR circuit, power of 400 W is dissipated from a source of 250 V, 50 Hz. The power factor of the circuit is 0.8. In order to bring the power factor to unity, a capacitor of value C is added in series to the L and R. Taking the value of C as $\left(\frac{n}{3\pi}\right)\mu F$, then value of n is _____. [6 Sep, 2020 (Shift-II)]

Transformer

111. Primary side of a transformer is connected to 230V, 50 Hz supply. Turns ratio of primary to secondary winding is 10 : 1. Load resistance connected to secondary side is 46Ω. The power consumed in it is: [27 Jan, 2024 (Shift-II)]
(a) 12.5 W (b) 10.0 W (c) 11.5 W (d) 12.0 W

112. Primary coil of a transformer is connected to 220 V ac. Primary and secondary turns of the transforms are 100 and 10 respectively. Secondary coil of transformer is connected to two series resistance shown in shown in figure. The output voltage (V_0) is: [30 Jan, 2024 (Shift-I)]



(a) 7 V (b) 15 V (c) 44 V (d) 22 V

113. A power transmission line feeds input power at 2.3 kV to a step down transformer with its primary winding having 3000 turns. The output power is delivered at 230 V by the transformer. The current in the primary of the transformer is 5A and its efficiency is 90%. The winding of transformer is made of copper. The output current of transformer is_____A. [30 Jan, 2024 (Shift-II)]

114. A transformer has an efficiency of 80% and works at 10 V and 4 kW. If the secondary voltage is 240 V, then the current in the secondary coil is: [1 Feb, 2024 (Shift-II)]
(a) 1.59 A (b) 13.33 A (c) 1.33 A (d) 15.1 A

115. A parallel plate capacitor has a capacitance C = 200 pF. It is connected to 230 V ac supply with an angular frequency 300 rad/s. The rms value of conduction current in the circuit and displacement current in the capacitor respectively are: [1 Feb, 2024 (Shift-I)]
(a) 1.38 μA and 1.38 μA (b) 14.3 μA and 143 μA
(c) 13.8 μA and 138 μA (d) 13.8 μA and 13.8 μA

116. Match the List-I with List-II.

	List-I		List-II
A.	AC generator	I.	Presence of both L and C
B.	Transformer	II.	Electromagnetic Induction
C.	Resonance phenomenon to occur	III.	Quality factor
D.	Sharpness of resonance	IV.	Mutual Inductance

Choose the correct answer from the options given below: [1 Feb, 2023 (Shift-I)]
(a) A → IV, B → II, C → I, D → III
(b) A → II, B → I, C → III, D → IV
(c) A → II, B → IV, C → I, D → III
(d) A → IV, B → III, C → I, D → II

117. An ideal transformer with purely resistive load operates at 12 kV on the primary side. It supplies electrical energy to a number of nearby houses at 120 V. The average rate of energy consumption in the houses served by the transformer is 60 kW. The value of resistive load (Rs) required in the secondary circuit will be ____mΩ. [6 April, 2023 (Shift-I)]

@NKE_PAPER@NLEDNET

118. Match List – I with List – II. **[25 June, 2022 (Shift-I)]**

List – I		List – II	
A.	AC generator	I.	Detects the presence of current in the circuit
B.	Galvanometer	II.	Converts mechanical energy into electrical energy
C.	Transformer	III.	Works on the principle of resonance in AC circuit
D.	Metal detector	IV.	Changes an alternating voltage for smaller or greater value

Choose the correct answer from the options given below:

(*a*) (A) – (II), (B) – (I), (C) – (IV), (D) – (III)
(*b*) (A) – (II), (B) – (I), (C) – (III), (D) – (IV)
(*c*) (A) – (III), (B) – (IV), (C) – (II), (D) – (I)
(*d*) (A) – (III), (B) – (I), (C) – (II), (D) – (IV)

119. A transformer operating at primary voltage 8kV and secondary voltage 160V serves a load of 80kW. Assuming the transformer to be ideal with purly resistive load and working on unity power factor, the loads in the primary and secondary circuit would be **[28 July, 2022 (Shift-II)]**

(*a*) 800Ω and 1.06Ω (*b*) 10Ω and 500Ω
(*c*) 800Ω and 0.32Ω (*d*) 1.06Ω and 500Ω

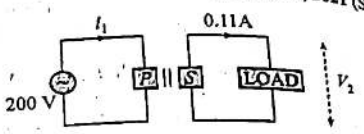
120. Match List I with List II. **[25 Feb, 2021 (Shift-II)]**

List – I		List – II	
A.	Rectifier	I.	Used either for stepping up or stepping down the a.c. voltage
B.	Stabilizer	II.	Used to convert a.c. voltage into d.c. voltage
C.	Transformer	III.	Used to remove any ripple in the rectified output voltage
D.	Filter	IV.	Used for constant output voltage even when the input voltage or load current change

Choose the correct answer from the options given below:

(*a*) (A) → (ii), (B) → (iv), (C) → (i), (D) → (iii)
(*b*) (A) → (iii), (B) → (iv), (C) → (i), (D) → (ii)
(*c*) (A) → (ii), (B) → (i), (C) → (iv), (D) → (iii)
(*d*) (A) → (ii), (B) → (i), (C) → (iii), (D) → (iv)

121. For the given circuit, comment on the type of transformer used. **[16 March, 2021 (Shift-II)]**



(*a*) Step down transformer (*b*) Auxilliary transformer
(*c*) Step- Up transformer (*d*) Auto transformed

122. A common transistor radio set requires 12V (D.C.) for its operation. The D.C. source is constructed by using a transformer and a rectifier circuit, which are operated at 220V (A.C.) on standard domestic A.C., supply. The number of turns of secondary coil are 24, then the number of turns of primary are_____. **[24 Feb, 2021 (Shift-I)]**

123. A power transmission line feeds input power at 2300 V to a step down transformer with its primary windings having 4000 turns, given the output power at 230 V. If the current in the primary winding of the transformer is 5A, and its efficiency is 90%, the output current would be **[9 Jan, 2019 (Shift-II)]**

(*a*) 20 A (*b*) 40A (*c*) 45A (*d*) 25A

124. A transformer consisting of 300 turns in the primary and 150 turns in the secondary gives output power of 2.2 *kW*. If the current in the secondary coils is 10A, then the input voltage and current in the primary coil are **[10 April, 2019 (Shift-I)]**

(*a*) 220 V and 10A (*b*) 440 V and 5A
(*c*) 440 V and 20A (*d*) 220 V and 20A

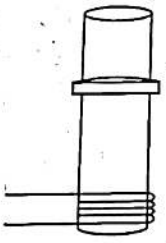
@FAKE_CBSE_KA_FRIEND

JEE-Advanced

Average Peak and RMS Value

Single Correct

1. **Statement-I:** A vertical iron rod has a coil of wire wound over it at the bottom end. An alternating current flows in the coil. There is a conducting ring round the rod as shown in the figure. The ring can float at a certain height above the coil. **(JEE Adv. 2007)**



Statement-II: In the above situation, a current is induced in the ring which interacts with the horizontal component of the magnetic field to produce an average force in the upward direction.

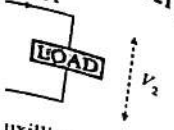
(*a*) Statement-I is True, Statement-II is True, Statement-II is a correct explanation for Statement-I
(*b*) Statement-I is True, Statement-II is True, Statement-II is NOT a correct explanation for Statement-I
(*c*) Statement-I is True, Statement-II is False
(*d*) Statement -I is False, Statement-II is True

Multiple Correct

2. The instantaneous voltages at three terminals marked *X*, *Y* and *Z* are given by $V_X = V_0 \sin \omega t$,

$$V_Y = V_0 \sin\left(\omega t + \frac{2\pi}{3}\right) \text{ and } V_Z = V_0 \sin\left(\omega t + \frac{4\pi}{3}\right).$$

he options given below:
(i), (D) → (iii)
(i), (D) → (ii)
iv), (D) → (iii)
iii), (D) → (iv)
he type of transformer used.
16 March, 2021 (Shift-II)]
0.11A



uxilliary transformer
ito transformed
12V (D.C.) for its operation.
a transformer and a rectifier
.C.) on standard domestic
econdary coil are 24, then

[24 Feb, 2021 (Shift-I)]
ower at 2300 V to a step
lings having 4000 turns,
current in the primary
efficiency is 90%, the
[9 Jan, 2019 (Shift-II)]
(d) 25A
in the primary and
ower of 2.2 kW. If the
the input voltage and

April, 2019 (Shift-I)]
d 5A
d 20A

induced in the ring
the magnetic field
tion.

Statement-II is a

tement-II is NOT

X, Y and Z are

An ideal voltmeter is configured to read rms value of the potential difference between its terminals. It is connected between points X and Y and then between Y and Z. The reading(s) of the voltmeter will be **C-3.91 W-33.26 UA-50.81 PC-12.02 (JEE Adv.2017)**

(a) $(V'_{YZ})_{rms} = V_0\sqrt{\frac{1}{2}}$

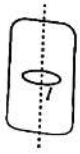
(b) $(V'_{XY})_{rms} = V_0\sqrt{\frac{3}{2}}$

(c) Independent of the choice of the two terminals

(d) $(V'_{XY})_{rms} = V'_0$

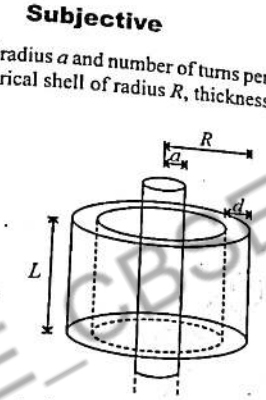
Numerical Types/Integer Types

3. A long circular tube of length 10 m and radius 0.3 m carries a current I along its curved surface as shown. A wire-loop of resistance 0.005 Ω and of radius 0.1 m is placed inside the tube with its axis coinciding with the axis of the tube. The current varies as $I = I_0 \cos 300\,t$ where I_0 is constant. If the magnetic moment of the loop is $N\mu_0 I_0 \sin(300t)$, then N is **(IIT-JEE 2011)**



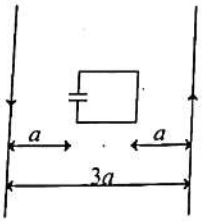
Subjective

4. A long solenoid of radius a and number of turns per unit length N is enclosed by cylindrical shell of radius R, thickness d ($d << R$) and length L.



A variable current $i = i_0 \sin \omega t$ flows through the solenoid. If the resistivity of the material of cylindrical shell is ρ, find the induced current in the shell. **(IIT-JEE 2005)**

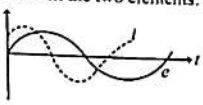
5. Two infinitely long parallel wires carrying currents $I = I_0 \sin \omega t$ in opposite directions are placed a distance $3a$ apart. A square loop of side a of negligible resistance with a capacitor of capacitance C is placed in the plane of wires as shown. Find the maximum current in the square loop. Also ketch the graph showing the variation of charge on the upper plate of the capacitor as a function of time for one complete cycle taking anti-clockwise direction for the current in the loop as positive. **(IIT-JEE 2003)**



A.C. Across L-R, L-C & RC

Single Correct

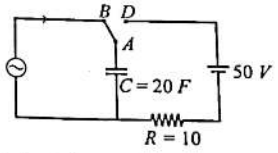
6. When an AC source of emf $e = E_0 \sin(100t)$ is connected across a circuit, the phase difference between the emf e and the current i in the circuit is observed to be $\frac{\pi}{4}$ ahead, as shown in the diagram. If circuit consists possibly only of R-C or R-L or L-C in series, find the relationship between the two elements. **(IIT-JEE 2003)**



(a) R = 1 kΩ, C = 10 μF (b) R = 1 kΩ, C = 1 μF
(c) R = 1 kΩ, L = 10H (d) R = 1 kΩ, L = 1H

Multiple Correct

7. At time $t = 0$, terminal A in the circuit shown in the figure is connected to B by a key and an alternating current $I(t) = I_0 \cos(\omega t)$, with $I_0 = 1A$ and $\omega = 500$ rad s^{-1} starts flowing in it with the initial direction shown in the figure. At $t = 7\pi/6\omega$, the key is switched from B to D. Now ohwards only A and D are connected. A total charge Q flows from the battery to charge the capacitor fully. If $C = 20$ μF, $R = 10$ Ω and the battery is ideal with emf of 50 V, identify the correct statement(s). **C-4.96 W-80.47 UA-14.57 (JEE Adv. 2014)**



(a) Magnitude of the maximum charge on the capacitor before $t = \frac{7\pi}{6\omega}$ is 1×10^{-3} C

(b) The current in the left part of the circuit just before $t = \frac{7\pi}{6\omega}$ is clockwise

(c) Immediately after A is connected to D, the current in R is 10 A

(d) $Q = 2 \times 10^{-3}$ C

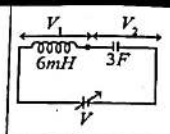
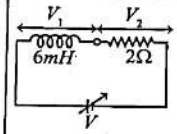
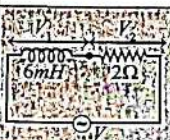
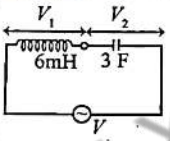
8. A series R-C circuit is connected to AC voltage source. Consider two cases; (A) when C is without a dielectric medium and (B) when C is filled with dielectric of constant 4. The current I_R through the resistor and voltage V_C across the capacitor are compared in the two cases. Which of the following is/are true? **(IIT-JEE 2011)**

(a) $I_R^A > I_R^B$ (b) $I_R^A < I_R^B$ (c) $V_C^A > V_C^B$ (d) $V_C^A < V_C^B$

Match the Column

9. You are given many resistances, capacitors and inductors. These are connected to a variable DC voltage source (the first two circuits) or an AC voltage source of 50 Hz frequency (the next three circuits) in different ways as shown in Column-II. When a current I (steady state for DC or rms for AC) flows through the circuit, the corresponding voltage V_1 and V_2 (indicated in circuits) are related as shown in Column-I. **(IIT-JEE 2010)**

@FIITJEE_CBSE_X@FIITJEENET

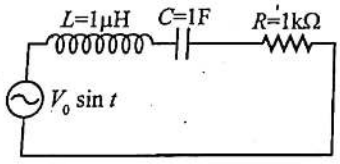
Column-I		Column-II	
(A)	$I \neq 0$ V_1 is proportional to I	(p)	
(B)	$I \neq 0$, $V_2 > V_1$	(q)	
(C)	$V_1 = 0$, $V_2 = V$	(r)	
(D)	$I \neq 0$ V_2 is proportional to I	(s)	
		(t)	

AC Source with RLC Connected in Series

Multiple Correct

10. In the circuit shown, $L = 1\mu H$, $C = 1\mu F$ and $R = 1\Omega$. They are connected in series with an AC source $V = V_0 \sin \omega t$ as shown. Which of the following options is/are correct?

C-23.34 W-20.54 UA-35.39 PC-20.73 (JEE Adv. 2017)



(a) At $\omega \approx 0$, the current flowing through the circuit becomes nearly zero

(b) The frequency at which the current will be in phase with the voltage is independent of R

(c) The current will be in phase with the voltage if $\omega = 10^4$ rads^{-1}

(d) At $\omega >> 10^6$, rads^{-1}, the current behaves like a capacitor

Match the Column

11. A series LCR circuit is connected to a 45 sin (ωt) Volt source. The resonant angular frequency of the circuit is 10^5 rad s^{-1} and current amplitude at resonance is I_0. When the angular frequency of the source is $\omega = 8 \times 10^4$ rad s^{-1}, the current amplitude in the circuit is $0.05\ I_0$. If $L = 50$ mH, match each entry in List-I with an appropriate value from List-II and choose the correct option.

C-8.97 W-31.39 UA-59.64 (JEE Adv. 2023)

List-I		List-II	
(p)	I_0 in mA	(i)	44.4
(q)	The quality factor of the circuit	(ii)	18
(r)	The bandwidth of the circuit in rad s^{-1}	(iii)	400
(s)	The peak power dissipated at resonance in Watt	(iv)	2250
		(v)	500

(a) $p \to (ii), q \to (iii), r \to (v), s \to (i)$

(b) $p \to (iii), q \to (i), r \to (iv), s \to (ii)$

(c) $p \to (iv), q \to (v), r \to (iii), s \to (i)$

(d) $p \to (iv), q \to (ii), r \to (i), s \to (v)$

Power Consumed in an AC Circuit

Single Correct

12. An AC voltage source of variable angular frequency ω and fixed amplitude V_0 is connected in series with a capacitance C and an electric bulb of resistance R (inductance zero). When ω is increased,

(IIT-JEE 2010)

(a) the bulb glows dimmer

(b) the bulb glows brighter

(c) total impedance of the circuit is unchanged

(d) total impedance of the circuit increases

L-C Oscillator

Single Correct

13. After the capacitor gets fully charged, S_1 is opened and S_2 is closed so that the inductor is connected in series with the capacitor. Then,

(IIT-JEE 2006)

(a) at $t = 0$, energy stored in the circuit is purely in the form of magnetic energy.

(b) at any time $t > 0$, current in the circuit is in the same direction.

(c) at $t > 0$, there is no exchange of energy between the inductor and capacitor.

(d) at any time $t > 0$, maximum instantaneous current in the circuit may be $V\sqrt{\frac{C}{L}}$

@TAKE_CBSE_X @RAJ_EDUNET

Numerical Types/Integer Types

14. Consider an LC circuit with inductance $L = 0.1\ H$ and capacitance $C = 10^{-3}\ F$, kept on a plane. The area of the circuit is 1 m^2. It is placed in a constant magnetic field of strength B_0 which is perpendicular to the plane of the circuit. At time $t = 0$, the magnetic field strength starts increasing linearly as $B = B_0 + \beta t$ with $\beta = 0.04 Ts^{-1}$. The maximum magnitude of the current in the circuit is _____ mA. **C-12.4 W-46.44 UA-41.11 (JEE Adv. 2022)**

Comprehension Based/Passage Based

Direction (Q. 75-76): A thermal power plant produces electric power of 600 kW at 4000 V, which is to be transported to a place 20 km away from the power plant for consumers' usage. It can be transported either directly with a cable of large current carrying capacity or by using a combination of step-up and step-down transformers at the two ends. The drawback of the direct transmission is the large energy dissipation. In the method of using transformers, the dissipation is much smaller. In this method, a step-up transformer is used at the plant side so that the current is reduced to a smaller value.

At the consumers' end, a step-down transformer is used to supply power to the consumers at the specified lower voltage. It is reasonable to assume that the power cable is purely resistive and the transformers are ideal with a power factor unity. All the current and voltages mentioned are rms values. **(IIT-JEE 2006)**

15. If the direct transmission method with a cable of resistance 0.4 Ω km^{-1} is used, the power dissipation (in %) during transmission is

(a) 20 (b) 30

(c) 40 (d) 50

16. In the method using the transformers, assume that the ratio of the number of turns in the primary to that in the secondary in the step-up transformer is 1:10. If the power to the consumers has to be supplied at 200V, the ratio of the number of turns in the primary to that in the secondary in the step-down transformer is

(a) 200 : 1 (b) 150 : 1

(c) 100 : 1 (d) 50 : 1

@TAKE_CBSE_X @RAJ_EDUNET

ANSWER KEY

JEE-Main

1. [8]	2. (a)	3. (a)	4. (d)	5. (a)	6. (a)	7. (b)	8. [11]	9. (c)	10. (b)
11. (a)	12. (a)	13. (b)	14. (a)	15. (b)	16. (b)	17. (c)	18. (d)	19. [242]	20. (d)
21. (b)	22. (a)	23. (d)	24. (a)	25. [22]	26. (a)	27. [3]	28. (d)	29. (d)	30. (c)
31. [1]	32. (b)	33. (a)	34. (b)	35. [6]	36. (b)	37. [1.00]	38. (c)	39. (d)	40. (d)
41. [50]	42. (c)	43. (3)	44. (10)	45. (b)	46. (4)	47. (c)	48. (a)	49. (b)	50. (c)
51. (a)	52. (d)	53. [25]	54. [3872]	55. [242]	56. [100]	57. [8]	58. [40]	59. (c)	60. (a)
61. (c)	62. (d)	63. [0]	64. (c)	65. [0]	66. [250]	67. [22]	68. [100]	69. [5]	70. (c)
71. (c)	72. (b)	73. (d)	74. (c)	75. (b)	76. (b)	77. (b)	78. (b)	79. (b)	80. [2000]
81. (c)	82. [125]	83. [500]	84. [400]	85. [2]	86. [3]	87. (a)	88. (c)	89. (*)	90. (c)
91. (c)	92. (d)	93. (250)	94. (c)	95. [3]	96. [15]	97. (b)	98. [975]	99. [900]	100. [4]
101. (a)	102. (a)	103. (c)	104. (a)	105. (a)	106. [9]	107. (b)	108. [10]	109. [4]	110. [400]
111. (c)	112. (a)	113. (45)	114. (b)	115. (d)	116. (c)	117. [240]	118. (a)	119. (c)	120. (a)
121. (c)	122. [440]	123. (c)	124. (b)						

JEE-Advanced

1. (a)	2. (b, c)	3. [6]	6. (a)	7. (c, d)	8. (b, c)				
9. (A) → r, s, t; (B) → q, r, s, t; (C) → q, p; (D) → q, r, s, t					10. (a, b)	11. (b)	12. (b)	13. (d)	14. [4]
15. (b)	16. (a)								

EXPLANATIONS

JEE-Main

1. [8] $I_{rms} = \sqrt{\frac{\int i^2 dt}{\int dt}} = \sqrt{(6)^2 + \frac{(\sqrt{56})^2}{2}}$

$= \sqrt{36+28} = \sqrt{64} = 8\ A$

2. (a) AC generator convert mechanical energy into electrical energy Galvanometer detect present current in any wire. Transformer is used to transform electrical energy from one AC circuit to another by reducing or increasing the voltage.

3. (a) $I = I_0 \cos\omega t$

$\frac{I_0}{\sqrt{2}} = I_0 \cos wt$

$\cos\left(\frac{\pi}{4}\right) = \cos\omega t$

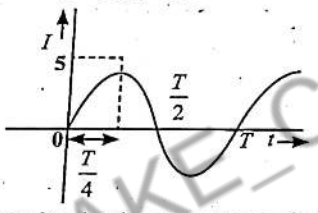
$t = \frac{\pi}{4\omega} = \frac{\pi}{4} \times \frac{T}{2\pi} = \frac{T}{8}$

$t = \frac{1}{8u} = \frac{1}{8 \cdot 50}$

$= 0.25 \times 10^{-2} = 2.5 \times 10^{-3}\ s = 2.5\ ms$

4. (d) Given, $I = 5\sin(120\pi t)$,
Comparing with $I = I_0 \sin(\omega t)$
$\omega = 120\pi$,

$\therefore T = \frac{2\pi}{\omega} = \frac{2\pi}{120\pi} = \frac{1}{60}$ sec,



Time taken by the current to reach the peak value $= \frac{T}{4} = \frac{1}{60\times4} = \frac{1}{240}$ sec

5. (a) $I = I_0 \cos\omega t$
Since, = current is changing from its maximum value to rms value therefore,
$I = I_0/\sqrt{2}$

$\therefore \frac{I_0}{\sqrt{2}} = I_0 \cos\omega t$

$\cos\omega t = \frac{1}{\sqrt{2}}$

$\cos(2\pi ft) = \cos\frac{\pi}{4}$

$\Rightarrow 2\pi \times 50t = \frac{\pi}{4}$ $t = 2.5\ ms$

6. (a) $I = I_1 \sin\omega t + I_2 \cos\omega t$
$I = I_1 \sin\omega t + I_2 \sin(\omega t + 90°)$

$I = \sqrt{I_1^2 + I_2^2}\sin(\omega t + \alpha)$

$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{\sqrt{I_1^2 + I_2^2}}{\sqrt{2}}$

7. (b) A hot wire ammeter reads rms value of current, so
$I = I_1 \sin\omega t + I_2 \cos\omega t$

$= \sqrt{I_1^2 + I_2^2}\ \sin(\omega t + \phi) = I_0 \sin(\omega t + \phi)$,

where $I_0 = \sqrt{I_1^2 + I_2^2}$

$\Rightarrow I_{rms} = \frac{I_0}{\sqrt{2}} = \sqrt{\frac{I_1^2 + I_2^2}{2}}$

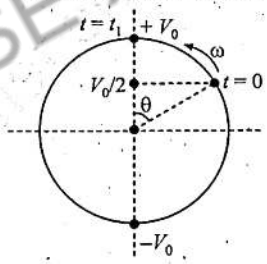
8. [11] For the current, $i(t) = A_0 \sin\omega t + B_0$

RMS value $= \sqrt{\frac{A_0^2}{2} + B_0^2}$

$I_{rms}^2 = \left(\frac{\sqrt{42}}{2}\right)^2 + 10^2 = 121$

$\Rightarrow I_{rms} = 11A$

9. (c) For pure resistance current is in same phase with V. Phase analysis



From figure $\cos\theta = \frac{V_0/2}{V_0} = \frac{1}{2}$

$\Rightarrow \theta = \frac{\pi}{3}$

time taken in phase change by $\frac{\pi}{3}$ is

$t_1 = \frac{\theta}{\omega} = \frac{\pi/3}{100\pi} = \frac{1}{300} = 3.33\ ms$

10. (b) V(t) = 220 sin 100(pi)t volt
Rising half to peak
t = T/6

$t = \frac{2\pi}{6\omega} = \frac{\pi}{3\omega} = \frac{\pi}{300\pi} = \frac{1}{300} = 3.33\ ms$

11. (a) $I_0 = \frac{E_0}{X_c} = \frac{E_0}{\frac{1}{\omega C}} = E_0\omega C.$

$I_0 = 36 \times 120\pi \times 150 \times 10^{-6}$ $(\because \omega = 120\pi)$

$I_0 = 2.03A$

12. (a) Inductive reactance, $X_L = \omega L = 628 \times 5 \times 10^{-3}$
$[\because \omega = 628\ rad/s, L = 5\ mH]$
$= 3.14\ \Omega$

13. (b) All the three have same dimensions, therefore $\frac{R}{\sqrt{X_L X_C}}$ must be dimensionless.

14. (a) $Q_f = CV_f$

$V = \frac{Q_f}{C} = \frac{5}{2 \cdot 10^{-6}} = 2.5 \cdot 10^{-6} V$

Since, $Q \propto V$ therefore there would be a straight line passing through origin.

15. (b) Formula of average power.
$P_{avg} = V_{rms} \cdot I_{rms} \cos\phi$
For purely inductive circuit, $\phi = \frac{\pi}{2}$

$\therefore \cos\frac{\pi}{2} = 0$
Average power = 0

16. (b) Current in capacitor, $I = \frac{V}{X_c} = \frac{V}{\frac{1}{\omega C}}$

$I = V \times (\omega C)$

$C = \frac{I}{V\omega} = \frac{6.9\times10^{-6}}{230\times600} = 50pF$

17. (c) We have, $E = 440\sin 100\pi t$
So, $\omega = 100\pi$

$L = \frac{\sqrt{2}}{\pi} H$

$X_L = \omega L = 100\sqrt{2}\Omega$

$i_{(ms)} = \frac{V_{(rms)}}{X_L} = \frac{440}{\sqrt{2}\times100\sqrt{2}} = 2.2A$

18. (d) We have, $i = 5\sin(49\pi t - 30°)$
$L = 30mH$, $\pi = \frac{22}{7}$

$X_L = \omega L = 49\pi \times 30 \times 10^{-3} = 462 \times 10^{-2}\ \Omega$
$V_0 = i_0 X_L = 5 \times 462 \times 10^{-2} = 23.1V$
So, $V_L = V_0 \sin(49\pi t - 30° + 90°)$ (Voltage will lead current by 90°)
$\Rightarrow V_L = 23.1\sin(49\pi t + 60°)$

@FAKE_CBSE_X @RAJ_EDUNET

$\frac{E_0}{X_c} = \frac{E_0}{\frac{1}{\omega C}} = E_0 \omega C$.

$20\pi \times 150 \times 10^{-6}$

$\{\because \omega = 120\pi\}$

ve reactance, $X_L = \omega L = 628 \times$

rad/s, L = 5 mH]

tree have same dimensions,

$\frac{R}{\omega L X_C}$ must be

i.

$\frac{5}{10^{-6}} = 2.5 \cdot 10^{-6} V$

herefore there would be a

sing through origin.

verage power.

$\cos\phi$

tive circuit, $\phi = \frac{\pi}{2}$

0

acitor, $I = \frac{V}{X_C} = \frac{V}{\frac{1}{\omega C}}$

$\frac{}{0} = 50 pF$

$0 \sin 100\pi t$

$\frac{40}{00\sqrt{2}} = 2.2A$

$(49\pi t - 30°)$

$0^{-3} = 462 \times 10^{-2}\Omega$

$10^{-2} = 23.1V$

$0° + 90°)$ (Voltage

)

$\cdot 60°)$

19. [242] $I_{rms} = \frac{I_0}{\sqrt{2}}$

$V_{rms} = I_{rms} Z$

$I_{rms} = \frac{I_0}{\sqrt{2}} \times X_L = \frac{I_0 \omega L}{\sqrt{2}} = \frac{I_0 (2\pi f) L}{\sqrt{2}}$

$I_0 = \frac{V_{rms} \times \sqrt{2}}{2\pi f L}$

$= \frac{220 \times \sqrt{2}}{2\pi \times 50 \times 200 \times 10^{-3}}$

$= \frac{220\sqrt{2}}{20\pi}$

$= \frac{11\sqrt{2}}{\pi} = \frac{\sqrt{a}}{\pi}$

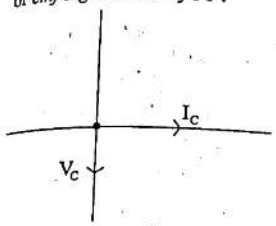
$a = 242$

20. (d) $X_L = \omega L$

$X_L' = \left(\frac{X_L}{2}\right)$

$\because I = \frac{V}{X_L}; I' = \frac{2V}{X_L} = 2I$

21. (b) In capacitive circuit, current leads *emf* or *emf* lags current by 90°.



22. (a) $I = I_0 \sin\omega t \Rightarrow \frac{I_0}{\sqrt{2}} = I_0 \sin\omega t$

$\Rightarrow \omega t = \frac{\pi}{4} \Rightarrow t = \frac{\pi}{4\omega} = \frac{\pi}{4(2\pi f)}$

$\Rightarrow t = \frac{1}{8 \times 30} = \frac{1}{400} = 2.5 ms$

23. (d) Given phase difference = $\frac{\pi}{4}$ and

$\omega = 100$ rad/s

$\Rightarrow$ Reactance (X) = Resistance (R)

Option (a)

$R = 1000\Omega$ and $X_C = \frac{1}{10^{-6} \times 100} = 10^4 \Omega$

Option (b)

$R = 10^3 \Omega$ and $X_L = 10^{-3} \times 100 = 10^{-1} \Omega$

Option (c)

$R = 10^3 \Omega$ and $X_L = 10 \times 10^{-3} \times 100 = 1\Omega$

Option (d), $R = 10^3 \Omega$ and

$X_C = \frac{1}{10 \times 10^{-6} \times 100} = 10^3 \Omega$

$\Rightarrow$ Option (d) matches the given condition.

24. (a) We have given that the voltage across resistance is 36 V, now

$36 = I_{rms} R$

As $V_R = 36V$

$36 = \frac{120}{\sqrt{X_L^2 + R^2}} \times R$

$\Rightarrow 36 = \frac{120 \times 90}{\sqrt{X_L^2 + 90^2}}$ [As $R = 90\Omega$]

$\sqrt{X_L^2 + 90^2} = 300 \Rightarrow X_L = 286.18$

$\omega L = 286.18$

$L = \frac{286.18}{376.8} = 0.76H$

25. [22] capacitance of the capacitor,

$C = 2\mu f; E = 110\sqrt{2}\sin(100t)$

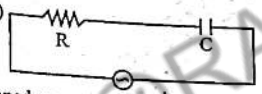
$X_C = \frac{1}{\omega c} = \frac{1}{100 \times 2 \times 10^6} = 5000\Omega$

$i_o = \frac{V_{Peak}}{X_C} = \frac{110\sqrt{2}}{5000}$

$i_{rms} = \frac{i_0}{\sqrt{2}} = \frac{110\sqrt{2}}{5000\sqrt{2}}$

$= \frac{110}{5} mA = 22 mA$

26. (a)



Impedence,

$Z = \sqrt{R^2 + X_C^2}$ & $X_C = \frac{1}{WC}$

Due to dielectric

$C\uparrow \Rightarrow X_C \downarrow \Rightarrow Z\downarrow$

Thus bulb will glow more brighter as current increases.

27. [3] From the formula of Power, resistance of the lamp.

$R = \frac{V^2}{P} = \frac{10000}{50} \Rightarrow R = 200\Omega$

$V^2 = V_c^2 + V_R^2$

$\Rightarrow 200 = \sqrt{V_c^2 + (100)^2}$

$\Rightarrow 40000 = V_c^2 + 10000 \Rightarrow V_c = 100\sqrt{3}$

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} = \frac{\pi\sqrt{x}\ S}{100\pi \times 50}$

$= \frac{\sqrt{x}}{5000 \times 10^{-6}} = \frac{\sqrt{x} \times 10^3}{5}$

From ohm's law, $I = \frac{100}{200} = 0.5A$

Potential drop accross capacitor, $V_C = IX_C$

$100\sqrt{3} = \frac{0.5 \times \sqrt{x} \cdot 10^3}{50}$

$1000\sqrt{3} = \sqrt{x} \cdot 10^3$

$\sqrt{x} = \sqrt{3} \Rightarrow x = 3$

28. (d) Given, $v = 100\sin\omega t$

$I_0 = \frac{100}{R_x} = 5 \Rightarrow R_x = 20\Omega = R_y$

$I = 5\sin\left(\omega t - \frac{\pi}{2}\right)$

When x and y both are connected in series:- $v = 100\sin\omega t$

$\tan\theta = 1 \Rightarrow \theta = 45°$

$R_0 = \sqrt{R_x^2 + R_y^2} = 20\sqrt{2}\Omega$

$\therefore I_0 = \frac{v_0}{R_0} = \frac{100}{20\sqrt{2}} = \frac{5}{\sqrt{2}} A.$

$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{5}{2} A$

29. (d) The capacitor gets repeatedly charged and discharged due to alternating square wave source.

During Charging Process:

$Q = CV_0\left(1 - e^{\frac{-t}{RC}}\right) \Rightarrow$ Charge on the capacitor, and

$V_C = \frac{Q}{C} = V_0\left(1 - e^{\frac{-t}{RC}}\right) \Rightarrow$ Potential difference across capacitor

During discharging Process.

$Q = Q_0 e^{\frac{1}{RC}} + CV_0\left(1 - e^{\frac{1}{RC}}\right) \Rightarrow$ Chargeon the capacitor,

30. (c) At $t = 0$, no current flows through inductor.

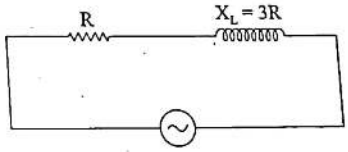
Equivalent resistance of the circuit

$R_{eq} = \frac{6 \times 9}{6 + 9} = \frac{18}{5}$

Current in the circuit $i = \frac{E}{\frac{18}{5}} = \frac{5E}{18}$

At $t = \infty$, current flows through circuit as if inductor is shorted.

$\therefore R_{eq} = \frac{5 \times 5}{5 + 5} + \frac{4 \times 1}{4 + 1} = \frac{33}{10}$

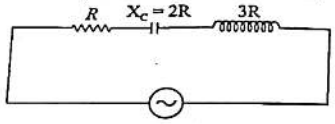


$i = \frac{E}{\frac{33}{10}} = \frac{10E}{33}$

@FAKE_CBSE_@RAJ_EDUNET

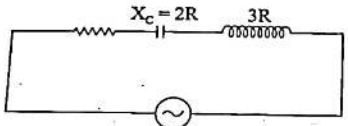
31. [1] Initially, $\cos\phi_1 = \frac{R}{\sqrt{R^2+(3R)^2}} = \frac{1}{\sqrt{10}}$

When capacitor is added in the circuit.



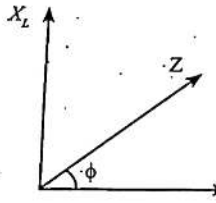
$$\cos\phi_2 = \frac{R}{\sqrt{R^2+(3R-R)^2}} = \frac{1}{\sqrt{2}}$$

$$\Rightarrow \frac{\cos\phi_2}{\cos\phi_1} = \frac{\sqrt{10}}{\sqrt{2}} = \sqrt{5} \Rightarrow x = 1$$



Hence, the correct value of x in the ratio $\sqrt{5} : x$ is 1.

32. (*b*) $L = 0.07$ H and $R = 12\ \Omega$, $V_s = 220$ V, 50 Hz



$$Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + (2\pi fL)^2}$$

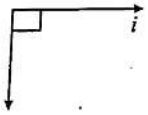
$$= \sqrt{12^2 + (7\pi)^2} \approx 25\Omega$$

Current, $\therefore i = \frac{V}{Z} = \frac{220V}{25\Omega} = 8.8A$

$$\tan\phi = \frac{X_L}{R} = \frac{7\pi}{12} \Rightarrow \phi = \tan^{-1}\left(\frac{11}{6}\right)$$

33. (*a*) $V = 10\sin(314t)$

$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$



$R = 0$

$$Z = X_C - X_L = \frac{1}{\omega C} - \omega L$$

$$= \frac{1}{3.14\times100\times10^{-6}} - 314\times40\times10^{-3}$$

$= 31.84 - 12.56 = 19.28\ \Omega$, $X_C > X_L$

$$i = \frac{V_0}{Z}\sin\left(314t + \frac{\pi}{2}\right)$$

$$\therefore\ i = \frac{V_0}{Z}\cos(314t)$$

$$\Rightarrow i = \frac{10}{19.28}\cos(314t)$$

$$\Rightarrow i = 0.52\cos(314t)$$

34. (*b*) $\frac{1}{2}Li^2 = \frac{1}{n}\frac{1}{2}Li_0^2$

$$\Rightarrow i = \frac{i_0}{\sqrt{n}}$$

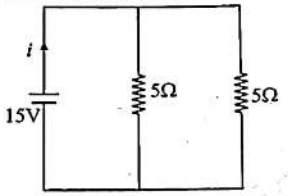
During growth of current,

$$i = i_0(1 - e^{-t/\tau}) \quad \left(\tau = \frac{L}{R}\right)$$

$$e^{t/\tau} = \frac{\sqrt{n}}{\sqrt{n}-1}$$

$$t = \frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}-1}\right)$$

35. [6] After long time, inductor will behave like wire of zero resistance.



$$i = \frac{15}{R_{eq}} = \frac{15}{(5/2)} = 6\ \text{A}$$

36. (*b*) $q = \int I\,dt$

$$q = \int_0^{L/R}\frac{E}{R}\left[1 - e^{\frac{-Rt}{L}}\right]dt \Rightarrow q = \frac{EL}{R^2}\frac{1}{e}$$

$$\Rightarrow q = \frac{EL}{2.7R^2}$$

37. [1.00] $X_L = \omega L = 2\pi\times50\times\frac{100}{\pi}\times10^{-3}$

$= 10\ \Omega$

$$X_C = \frac{1}{\omega C} = \frac{\pi}{2\pi\times50\times10^{-3}} = 10\Omega$$

$\because X_C = X_L$, Hence, circuit is in resonance

$\therefore$ power factor $= \frac{R}{Z} = \frac{R}{R} = 1$

38. (*c*) According to given condition,

$\omega' = \omega$

$$\frac{1}{\sqrt{L'C'}} = \frac{1}{\sqrt{LC}}$$

$\therefore L'C' = LC$

$L'(4C) = LC$

$$L' = \frac{L}{4}$$

39. (*d*) This is possible when phase difference is $\frac{\pi}{2}$ between current and voltage.

40. (*d*) For A – potential lags by 90° from current therefore (I) is correct.
For B– potential lead by 90° from current therefore (IV) is correct
For C– In LCR resonance $X_L = X_C$ therefore circuit is purely resistive so (II) is correct
For D– In LCR series potential is at some angle from current therefore (III) is correct

41. [50] Here, $X_L = \omega L = 100\times1 = 100\Omega$

$$X_C = \frac{1}{\omega C}$$

$$= \frac{1}{100\times20\times10^{-6}} = 500\Omega$$

Impedance of the a.c. source,

$$Z = \sqrt{(X_L - X_C)^2 + R^2}$$

$$\sqrt{(100-500)^2 + 300^2}$$

$= 500\ \Omega$

$$= \frac{V_{rms}}{Z} = \frac{50}{500} = \frac{1}{10}A$$

= voltage across capacitor

$= X_C i_{rms}$ [RMS]

$= 500\times0.1 = 50$V

42. (*c*) Voltage across inductor $V_L = IX_L$

$31.4 = I[L\omega]$

$31.4 = I[L(2\pi f)]$

$31.4 = I[10\times10^{-3}(2\times3.14)\times50$

$\Rightarrow I = 10$ A

43. (3) Current in $L\,C\,R$ circuit

$$I = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$$

at resonance $X_L = X_C$

Therefore, $I_o = \frac{V_o}{R}$ (I is maximum)

For purely resistive circuit.

$$I = \left(\frac{V}{R}\right)$$

So statement II is also correct.

44. (10) $f_0 = \frac{1}{2\pi\sqrt{L\times C}}$

$$= \frac{1}{2\pi\sqrt{100\times10^{-3}\times2.5\times10^{-9}}}$$

$f_0 = 10\times10^3$ Hz

45. (*b*) In resonance Impedance is equal to resistance.

$$I = \frac{V}{R}$$

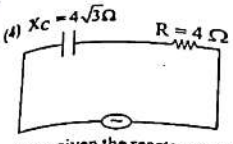
$R \rightarrow$ halved

$\Rightarrow I \rightarrow 2I$

I becomes doubled.

@TAKE_CBSE_K @RAJ_BSNET

(4) $X_C = 4\sqrt{3}\Omega$, $R = 4\ \Omega$



We have given the reactance of capacitor

$(X_L) = 4\sqrt{3}\Omega$

$Z = \sqrt{R^2 + X_L^2}$

$Z = \sqrt{4^2 + (4\sqrt{3})^2} = 8\Omega$

$V_{rms} = \frac{V}{\sqrt{2}} = \frac{8\sqrt{2}}{\sqrt{2}} = (8\,V)$

$I_{rms} = \frac{V_{rms}}{Z} = \frac{8}{8} = 1A$

Power dissipated

$= I_{rms}^2 \times R = 1 \times 4 = (4W)$

47. (c) Since, $X_L = 2\pi fL$ and $X_c = \frac{1}{2\pi fc}$

Therefore, curve A is X_C and curve B is X_L.

48. (a) Independence Z of the circuit is,

$Z = \sqrt{100^2 + (200-100)^2} = 100\sqrt{2}\Omega$

$i_{rms} = \frac{V_{rms}}{Z} = \frac{200\sqrt{2}}{100\sqrt{2}} \Rightarrow i_{rms} = 2A$

49. (b) $P = \frac{R}{Z} \Rightarrow P_1 = \frac{R}{\sqrt{R^2 + X_L^2}} = \frac{R}{R\sqrt{2}}$

(as $X_L = R$) $P_1 = \frac{1}{\sqrt{2}}$

$P_2 = \frac{R}{\sqrt{R^2 + (X_L - X_L)^2}} = P_2 = 1$

$\frac{P_1}{P_2} = \frac{1}{\sqrt{2}}$

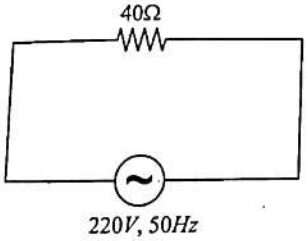
50. (c) Maximum power is dissipated in a circuit under resonance condition.

At resonance, $X_L = X_C$

$\therefore Z = \left[R^2 + (X_L - X_C)^2\right]^{\frac{1}{2}}$

$Z_{min} = R$

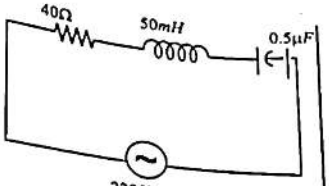
51. (a) For the circuit in Fig (A)



$220V, 50Hz$

$I_{rms} = \frac{220}{40} = 5.5\,A$

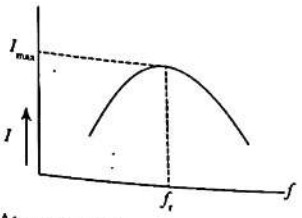
For the circuit in Fig (B)



$220V, 50Hz$

X_L is not equal to X_C. So rms current in fig (B) can never be larger than the rms current in Fig (A).

52. (d)



At resonance frequency power factor of L-C-R circuit is 1 i.e. $\cos\phi = 1$

53. [25] It is given that,

For a RLC circuit, $R = 80\,\Omega$, $X_L = 100\Omega$, $X_C = 40\Omega$.

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

$\sqrt{80^2 + (100-40)^2} = 100\Omega$

$i_0 = \frac{V_0}{Z} = \frac{2500}{100} = 25A$

54. [3872] At resonance $X_C = X_L$

$\Rightarrow \frac{1}{2\pi fC} = 2\pi fL$

$\Rightarrow C = \frac{1}{4\pi^2 f^2 L}$

$= \frac{1}{4 \times \pi^2 \times 49 \times 10^6 \times 2 \times 10^{-6}}$

$\Rightarrow C = \frac{1}{3872} F$

$\therefore x = 3872$

55. [242] At Resonance, $X_L = X_C$

$\Rightarrow Z = R = 20\Omega$

$i_{rms} = \frac{220}{20} = 11$

$i_{max} = i_{rms} \times \sqrt{2} = 11\sqrt{2} = \sqrt{242}$

56. [100] Resonant frequency $f = \frac{1}{2\pi\sqrt{LC}}$

$\Rightarrow 2000\,Hz = \frac{1}{2\pi\sqrt{L \times 62.5 \times 10^{-9}}}$

$\Rightarrow L = 0.1H = 100mH$

57. [8] $\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + (X_C - X_L)^2}}$

$\cos\phi = \frac{80}{\sqrt{(80)^2 + (60)^2}}$

$\cos\phi = \frac{8}{10} \Rightarrow x = 8$

58. [40] To maximize the Power.

LCR circuit will be in resonance condition

$\Rightarrow X_L = X_C$

$\Rightarrow 79.6 = \frac{1}{\omega C}$

$\therefore C = \frac{1}{2p' 50' 79.6} = 40\ mF.$

59. (c) We know that,

$I = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{V}{Z}$

According to the diagram current increases as ω increases and we know that for a capacitive circuit,

$I \alpha \frac{1}{X_c} \alpha\ \omega$

Therefore for $\omega < \omega_r$, the circuit is mainly capacitive.

At $\omega = \omega r$, $X_L = X_C$

$z = \sqrt{R^2 + (X_L - X_C)^2}$

$z = R\ [\because X_L = X_C]$

60. (a) We have, $V = 210 \sin 300\,t$

$\omega = 3000$

$\therefore X_L = \omega L = 30$

$X_c = \frac{1}{\omega c} = \frac{40}{3}$

$\tan f = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$

$\Rightarrow \tan\phi = \frac{30 - \frac{40}{3}}{100} = 0.17$

$\Rightarrow \phi = \tan^{-1}(0.17)$

61. (c) $f = \frac{1}{2\pi\sqrt{LC}}$, $f\ \mu\ \frac{1}{\sqrt{C}}$

On decreasing C, frequency would lincrease therefore, another capacitor should be added in series with the first capacitor.

62. (d) Dimension

RC is time constant, therefore, $[RC] = [T]$

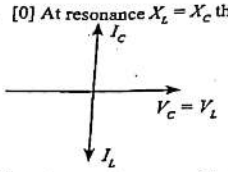
$\frac{L}{R}$ is time constant, therefore, $\left[\frac{L}{R}\right] = [T]$

$\sqrt{Lc}$ is reciprocal of angular frequency, therefor will have dimension equal time

$\frac{L}{C}$ is dimensionless.

@FAKE_CBSE_TORAJ_EDUNET

63. [0] At resonance $X_L = X_C$ then $I_L = I_C$



So, net current = zero $= (I_L = I_C)$

Therefore current through R at resonance be zero.

64. (c) Given, Frequency $\omega = 40\ \%$ of ω_0

$$\omega = 0.4 \times \frac{1}{\sqrt{LC}} = 0.4 \times \frac{1}{\sqrt{0.01 \times 1 \times 10^{-6}}}$$

$= 0.4 \times 10^4$ rad/s

Impedance of the circuit

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{(10)^2 + \left(\frac{0.4 \times 10^4 \times 0.01 - }{0.4 \times 10^4 \times 1 \times 10^{-6}}\right)^2}$$

$$= \sqrt{100 + \left(0.4 \times 100 - \frac{100}{0.4}\right)^2} = 210.$$

$$i_0 = \frac{V_0}{Z} = \frac{50}{210} = 0.238 A = 238 mA$$

65. [0] Given, $V_L = V_C = 2\ V_R$ [Resonance condition]

$\therefore V_L = 2 \times 220 = 440$ V

Current through the circuit,

$$I = \frac{220}{5} = 44A$$

$$\therefore V_L = I \times X_L = 440 \text{ V}$$

$$\Rightarrow X_L = \frac{440}{44} = 10A$$

$$\Rightarrow L \times 2\pi \times 50 = 10$$

$$\Rightarrow L = \frac{10}{100\pi} = \frac{1}{10\pi} = \frac{100}{\pi} \text{mH}$$

Comparing with $L = \frac{1}{K\pi}$ mH, we get $K = 0.01$

66. [250] Bandwidth, $\Delta\omega = \omega_2 - \omega_1 = \frac{R}{L}$

$$\Rightarrow L = \frac{R}{\Delta\omega} = \frac{5}{20} = .25H = 250 \text{ mH}$$

67. [22] $w = 2pf = 2p' 50 = 100p$

$$X_L = \omega L = 10\pi$$

$$X_c = \frac{1}{\omega C} = \frac{100}{\pi}$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\Rightarrow Z = \sqrt{100 + \left(10\pi - \frac{100}{\pi}\right)^2} = 10.0086\Omega$$

$$I = \frac{V}{Z} = \frac{220}{10.008} = 22A$$

68. [100] Capacitance, $C = 0.01 \times 10^{-6} \times 100 = 1 \times 10^{-6} F$

Frequency, $f = 0.5 \times 10^3 s^{-1}$

For minimum impedance:

$x_L = x_C$

$$\Rightarrow \omega^2 = \frac{1}{LC} \Rightarrow (2\pi f)^2 = \frac{1}{LC}$$

$$L = \frac{1}{4\pi^2 f^2 C}$$

$$= \frac{1}{4 \times (3.14)^2 \times (0.5 \times 10^3) \times 1 \times 10^{-6}}$$

$= 10^{-1}$ H $= 100$ mH

69. [5] It is given that, the current and voltage are in phase. Therefore, condition of resonance occurs.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2\pi\sqrt{\left(0.5 \times 10^{-3}\right) \times \left(200 \times 10^{-6}\right)}}$$

$$\Rightarrow f = \frac{10^4}{2\pi\sqrt{10}} \approx 5 \times 10^2 \text{ Hz}$$

[Taking $\pi = \sqrt{10}$]

70. (c) We have given,

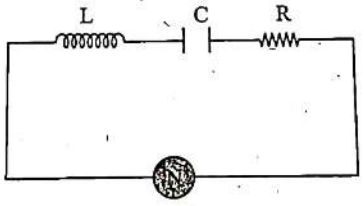
$\omega = 100\pi$, $R = 100\Omega$

$\therefore X_L = L\omega = 0.5 \times 10^{-3} \times 100\pi = 5\pi \times 10^{-2}\Omega$, and

$$X_C = \frac{1}{C\omega} = \frac{1}{0.1 \times 10^{-12} \times 100\pi} = \frac{10^{11}}{\pi}\Omega$$

$\because X_C >> X_L$

So the phase angle between current and supplied voltage and the nature of the circuit is $\approx 90°$, predominantly capacitive circuit



71. (c) When key is open current in the circuit

$$i_{rms} = \frac{15}{60} = \frac{1}{4} A$$

Therefore, $20 = i_{r.m.s.} \times L$

$$20 = \frac{1}{4} \times 100 \times L \Rightarrow L = 0.8 \text{ H}$$

And $10 = i_{r.m.s.} \times C$

$$10 = \frac{1}{4} \cdot \frac{1}{100C} \Rightarrow C = 2.5 \times 10^{-4} F = 250\ \mu F$$

72. (b) In purely resistive AC circuit, if $V = V_0 \sin(\omega t)$ then

$$I = \frac{V_0}{X_C} \sin\left(\omega t - \frac{\pi}{2}\right)$$

In LCR series AC circuit, phase difference between current and voltage, $\phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$.

73. (d) Impedance of the circuit,

$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$

$$Z = \sqrt{R^2 + (R - R)^2}$$

[$\because X_L = X_C = R \rightarrow$ Given]

$Z = R$

74. (c) Impedance of circuit,

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\Rightarrow Z = \sqrt{(120)^2 + (10 - 100)^2} = 150\Omega$$

So peak current, $I_0 = \frac{V_0}{Z} = \frac{30}{150} = 0.2A$

For restaurant frequency

$X_L = X_C$

$$\omega L = \frac{1}{\omega C}, \quad \omega^2 = \frac{1}{LC}$$

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{10^{-1} \times 10^{-4}}} = \sqrt{10^5}$$

$$\because \omega = 2\pi f$$

$$\therefore f = \frac{\sqrt{10^5}}{2\pi} = 50 Hz$$

75. (b) When capacitor is removed.

$$\tan 45^0 = \frac{X_L}{X_R} \Rightarrow \omega L = R$$

When inductor is removed.

$$\tan 45^0 = \frac{X_C}{X_R} \Rightarrow \frac{1}{\omega C} = R$$

$$i_0 = \frac{V_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} = \frac{V_0}{R} = \frac{220}{110} = 2A$$

76. (b) Given, $X_L = 250\pi\Omega\ f = 50H_z$

At resonance, power is maximum

$$\therefore X_L = X_C = \frac{1}{\omega C}$$

$$\Rightarrow C = \frac{1}{\omega X_L} = \frac{1}{(2\pi f) X_L}$$

$$= \frac{1}{2\pi \times 50 \times 250\pi} = \frac{1}{250 \times 100 \times \pi^2}$$

$= 4\mu F\ [\pi^2 = 10]$

@FAKE_CBSE_X @RAJ_EDUNET

$\frac{V_0}{X_C}\sin\left(\omega t-\frac{\pi}{2}\right)$

...ien ...ve AC circuit, it

CR series AC circuit, phase

...rence between current and

...ge, $\phi=\tan^{-1}\left(\frac{X_C-X_L}{R}\right)$.

...pedance of the circuit,

$\sqrt{R^2+(X_C-X_L)^2}$

$\sqrt{?^2+(R-R)^2}$

$X_C=R$ → Given]

...dance of circuit,

$\sqrt{R^2+(X_L-X_C)^2}$

$\sqrt{(120)^2+(10-100)^2}=150\Omega$

...urrent, $I_0=\frac{V_0}{Z}=\frac{30}{150}=0.2A$

...ant frequency

$\omega^2=\frac{1}{LC}$

$\frac{1}{\sqrt{10^{-1}\times10^{-4}}}=\sqrt{10^5}$

$50\,Hz$

...citor is removed.

$\Rightarrow \omega L=R$

...is removed.

$\frac{1}{\omega C}=R$

$\sqrt{R^2+\left(\frac{1}{\omega C}\right)^2}=\frac{V_0}{R}=\frac{220}{110}=2A$

$50\pi\Omega\, f=50H_2$

...ver is maximum

$\frac{1}{\pi f)X_L}$

$\frac{1}{250\times100\times\pi^2}$

77. (b) Let, current through inductor,

$i_L=I_L\sin(\omega t+\phi_1)$

$I_L=\frac{200\sqrt{2}}{\sqrt{50^2+(100\times0.50)^2}}=4A$

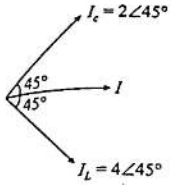
$\phi_1=\tan^{-1}\left(\frac{-100\times0.50}{50}\right)=-\frac{\pi}{4}$

Let, current through capacitor,

$i_c=I_c\sin(\omega t+\phi_2)$

$I_c=\frac{200\sqrt{2}}{\sqrt{100^2+\left(\frac{1}{100\times100\times10^{-6}}\right)^2}}=2A$

$\phi_2=\tan^{-1}\left(\frac{\frac{1}{100\times100\times10^{-6}}}{100}\right)=\frac{\pi}{4}$



As $\phi_2-\phi_1=\frac{\pi}{2}$.

$I=\sqrt{I_L^2+I_C^2}=\sqrt{4^2+2^2}=4.47\,A$

78. (b) (A) $\omega L>\frac{1}{\omega C}\Rightarrow X_L>X_C$

$\Rightarrow$ Current lags the emf.

$\Rightarrow$ Voltage leads the current.

(B) $\omega L=\frac{1}{\omega C}\Rightarrow X_L=X_C$

$\Rightarrow$ Current and emf are in same phase.

(C) $\omega L<\frac{1}{\omega C}\Rightarrow X_L<X_C$

$\Rightarrow$ Current leads the emf.

$\Rightarrow$ Voltage lags the current.

(D) Resonant frequency $\Rightarrow$ Maximum current occurs.

79. (b) $w=2pf=\frac{1}{\sqrt{LC}}$

Inductance,

$L=\frac{1}{4p^2f^2\cdot C}=\frac{1}{4p^2\cdot(60)^2\cdot10^{-7}}$

$\Rightarrow L=70.3\,H$

80. [2000] Quality factor

$=\frac{\omega L}{R}=\frac{2\times3.14\times10\times10^6\times2\times10^{-4}}{6.28}=2000$

81. (c) Given: $X_L=10\Omega$, $X_C=45\Omega$, $R=6\Omega$

$\therefore$ Power factor $=\cos\theta=\frac{R}{Z}$

$=\frac{R}{\sqrt{R^2+(X_L-X_C)^2}}$

$=\frac{6}{\sqrt{6^2+(10-4)^2}}=\frac{6}{6\sqrt{2}}=\frac{1}{\sqrt{2}}$

82. [125] At resonance, $\cos\phi=1$

$\therefore P=V_{rms}I_{rms}\cos\phi$

$=V_{rms}I_{rms}=V_{rms}\times\frac{V_{rms}}{R}=\frac{V_{rms}^2}{R}=\frac{250^2}{5}$

$=12500$ Watt $=125\times102$ Watt

83. [500] Since, power dissipated is same, therefore,

$P_1=P_2$

$\frac{220\times220}{5}=220\times\frac{220}{z}\times\frac{5}{z}$

$z=R=5$

Angular frequency,

$\omega=\frac{1}{\sqrt{LC}}$

$\omega=\frac{1}{\sqrt{0.1\times40\times10^{-6}}}=\frac{1}{2\times10^{-3}}$

$\omega=500$ rad/s

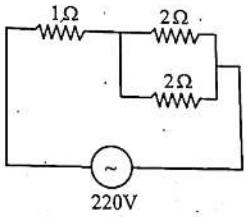
84. [400] As we know that $Q=\frac{wL}{R}$

[L Inductance and R is Resistance]

$\Rightarrow\frac{Q'}{Q}=\frac{L'}{R'}\times\frac{R}{L}=\left(\frac{L'}{L}\right)\times\left(\frac{R}{R'}\right)=2\times2$

$\Rightarrow Q'=4Q=4\times100=400$

85. [2] $X_c=\frac{1}{\omega C}$ and $X_L=\omega L$



At very high frequencies capacitor behaves as short circuit acts as open circuit. The effective impedance will be 2 Ω.

86. [3] Given, current leads the voltage by 45° phase difference.

$\therefore\tan45°=\frac{X_C-X_L}{R}\Rightarrow X_C=R+X_L$

$\Rightarrow\frac{1}{C\times300}=1+30\times10^{-3}\times300$

$\Rightarrow\frac{1}{C\times300}=10$

$\therefore C=\frac{1}{3}\times10^{-3}\,F$

87. (a) $Q=\frac{1}{R}\sqrt{\frac{L}{C}}$

$=\frac{1}{100}\sqrt{\frac{80\times10^{-3}}{2\times10^{-6}}}=2$

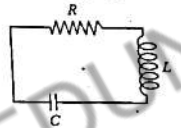
88. (c) For damped oscillation, Newton's second law,

$ma+bv+kx=0$

$m\frac{d^2x}{dt^2}+b\frac{dx}{dt}+kx=0$ ...(i)

Using KVL

$-iR-L\frac{di}{dt}-\frac{q}{c}=0$



$L\frac{d^2q}{dt^2}+R\frac{dq}{dt}+\frac{1}{c}q=0$ ...(ii)

Thus on comparing equation (i) and (ii)

$m=L, b=R, k=\frac{1}{c}$

89. (*) For C-R_2 circuit the capacitive reactance is

$X_c=\frac{1}{\omega C}=\frac{1}{100\times\frac{\sqrt{3}}{2}\times10^{-6}}=\frac{2\times10^4}{\sqrt{3}}\Omega$

Phase difference of I_2 with AC source is

$\phi_2=\tan^{-1}\frac{X_C}{R_2}=\tan^{-1}\left(\frac{2\times10^4}{20\times\sqrt{3}}\right)$

$=\tan^{-1}\left(\frac{1000}{\sqrt{3}}\right)=89.9°$(leading)

For L-R_1 circuit branch, inductive reactance is

$X_L=\omega L=100\times\frac{\sqrt{3}}{10}=10\sqrt{3}\Omega$

Phase difference of I_1 with AC source is

$\phi_1=\tan^{-1}\frac{X_L}{R_1}=\tan^{-1}\left(\frac{10\sqrt{3}}{10}\right)$

$=60°$ (lagging)

Phase difference between I_2 & I_2 is ϕ_T

$=\phi_1+\phi_2$

$=89.9°+60°$

$=149.9°\simeq150°$

None of the given options is correct.

@FAKE_CBSE_X@RAJ_EDUNET

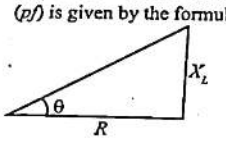
90. (c) The average power dissipated in one cycle

$P_{avg} = V_{ms}\, I_{ms} \cos(\Delta\phi)$

$= \frac{100}{\sqrt{2}} \times \frac{100\times10^{-3}}{\sqrt{2}} \times \cos\left(\frac{\pi}{3}\right)$

$= \frac{10^4}{2} \times \frac{1}{2} \times 10^{-3} = \frac{10}{4} = 2.5\ W$

91. (c) In an $L-R$ circuit, the power factor (pf) is given by the formula:



$$pf = \cos(\phi) = \frac{R}{\sqrt{R^2 + (\omega L)^2}}$$

$$\Rightarrow \tan(\phi) = \frac{X_L}{R}$$

Here, $X_L = \omega L$

Now here in first case, given

$E = 25 \sin(1000\ t)$

$$\cos\phi = \frac{1}{\sqrt{2}}$$

$$\Rightarrow \tan(\phi) = \frac{\omega_1 L}{R} = 1 \qquad ...(i)$$

For 2nd case,

$E = 20 \sin(2000\ t)$

From this we can conclude that, $\omega_2 = 2\omega_1$,

Hence,

$$\tan(\phi) = \frac{\omega_2 L}{R} = \frac{2\omega_1 L}{R} \qquad ...(ii)$$

From equation (i) and (ii),

$\tan(\phi)' = 2$

$$\Rightarrow \cos(\phi)' = \frac{1}{\sqrt{5}}$$

92. (d) $P = VI\cos\phi$

$$= \frac{10}{\sqrt{2}} \times \frac{20}{\sqrt{2}} \times \cos 60^\circ = 50W$$

93. (250) For DC voltage, Resistance of the circuit

$$R = \frac{V}{I} = \frac{100}{5} = 20\,\Omega$$

For AC voltage

$X_L = 20\sqrt{3}\,\Omega$

$R = 20\,\Omega$

Impedance $Z = \sqrt{X_L^2 + R^2}$

$= \sqrt{3\times400 + 400} = 40\,\Omega$

$$i_{rms} = \frac{V_{rms}}{2} = \frac{200}{\sqrt{2}} A$$

Power $= i_{rms}^2 R$

$$= \left(\frac{200}{\sqrt{2}}\right)^2 \times 20 = 250W$$

94. (c) The reactance of an ac circuit is zero only if capacitive reactance is equal to inductive reactance. Statement II is incorrect. In an ac circuit, average power will be zero when power factor becomes zero.

95. [3] From the formula of Power, resistance of the lamp.

$$R = \frac{V^2}{P} = \frac{10000}{50} \Rightarrow R = 200\Omega$$

$V^2 = V_c^2 + V_R^2$

$\Rightarrow 200 = \sqrt{V_c^2 + (100)^2}$

$\Rightarrow 40000 = V_c^2 + 10000 \Rightarrow V_c = 100\sqrt{3}$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} = \frac{\pi\sqrt{x}}{100\pi\times50} S$$

$$= \frac{\sqrt{x}}{5000\times10^{-6}} = \frac{\sqrt{x}\times10^3}{5}$$

From ohm's law, $I = \frac{100}{200} = 0.5A$

Potential drop accross capacitor, $V_C = IX_C$

$$100\sqrt{3} = \frac{0.5\times\sqrt{x}\cdot10^3}{50}$$

$1000\sqrt{3} = \sqrt{x}\cdot10^3$

$\sqrt{x} = \sqrt{3} \Rightarrow x = 3$

96. [15] Impedance of the circuit

$$Z = \sqrt{R^2 + (x_L - x_C)^2}$$

$$= \sqrt{R^2 + \left(\omega_L - \frac{1}{\omega_C}\right)^2}$$

$$= \sqrt{(120)^2 + \left[\frac{100\times100\times10^{-3}}{1} - \frac{1}{100\times100\times10^{-6}}\right]^2}$$

$= \sqrt{(120)^2 + (90)^2} = 150\Omega$

Current in the circuit,

$$I = \frac{V_{r.m.s}}{Z} = \frac{\left(\frac{V_0}{\sqrt{2}}\right)}{Z} = \frac{20}{150} = \frac{2}{15}$$

Now, Heat dissipated in the resistor = $ms\Delta T$

$I^2R\Delta t = ms\Delta T$

$$\Delta t = \frac{(ms\Delta T)}{I^2 \cdot R} = \frac{(2\times16)}{\left(\frac{2}{15}\right)^2 \times 120} = 15 \text{ sec.}$$

97. (b) For DC current $H_{DC} = iR_1 t$ and AC $H_{AC} = i_{rms}^2 R_2 t$

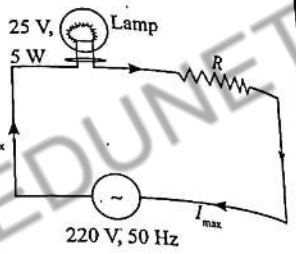
$$\frac{H_{DC}}{H_{AC}} = \frac{i^2}{i_{rms}^2}\frac{R_1}{R_2} = \frac{(4)^2}{\left(\frac{4}{\sqrt{2}}\right)^2}\frac{3}{2} = 3:1$$

98. [975] For lamp, $P = \frac{V^2}{R}$

$$\Rightarrow R = \frac{25\times25}{5} = 125\Omega$$

From ohm's law

$$I_{max} = \frac{V}{R} = \frac{25}{125} = \frac{1}{5} A$$



$$\Rightarrow I_{max} = \frac{220}{125+R} = \frac{1}{5} \Rightarrow 1100 = 125 + R$$

$R = 975\Omega$

99. [900] Given, $\omega_0 = 10^5$ rad/sec

$P = 16$ W, 120 V at resonance

$$P = \frac{V^2}{R} \Rightarrow 16 = \frac{(120)^2}{R} \Rightarrow R$$

$$= \frac{14400}{16} = 900\Omega$$

100. [4] Under resonant condition,

$$P = \frac{(V_{rms})^2}{R} = \frac{\left(\frac{V_0}{\sqrt{2}}\right)^2}{R}$$

$$= \frac{250\times250}{2\times8} \approx 4kW$$

101. (a) Power delivered = 1000 W

Voltage = 220 V

The current through the power line is, I

$$= \frac{1000}{220} = \frac{50}{11} A$$

Power loss $= I^2R = \left(\frac{50}{11}\right)^2 \times 2 = 41.322W$

Efficiency

$$= \frac{1000\times100}{1000 + I^2R}$$

$$= \frac{1000\times100}{1000 + 41.322} \times 100 = 96\%$$

@FAKE_CBSE_X_@RAJ_EDUNET

$\cdots = i_{rms}^2 R_2 t$

$\frac{H_{DC}}{H_{AC}} = \frac{i^2 R_1}{i_{rms}^2 R_2} = \frac{(4)^2}{\left(\frac{4}{\sqrt{2}}\right)^2}\frac{3}{2} = 3:1$

] For lamp, $P = \frac{V^2}{R}$

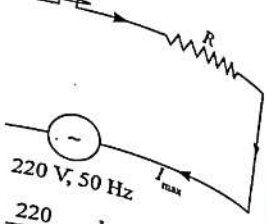
$R = \frac{25\times25}{5} = 125\Omega$

m ohm's law

$= \frac{V}{R} = \frac{25}{125} = \frac{1}{5}A$

5 V, Lamp

W



$\frac{220}{25+R} = \frac{1}{5} \Rightarrow 1100 = 125 + R$

, $\omega_0 = 10^5$ rad/sec

20 V at resonance

$= \frac{(120)^2}{R} \Rightarrow R$

900Ω

nant condition,

$\frac{\left(\frac{V_0}{\sqrt{2}}\right)^2}{R}$

4kW

ed = 1000 W

h the power line is, *I*

$\left(\frac{50}{1}\right)^2 \times 2 = 41.322W$

$00 = 96\%$

102. (a) $H = (I_{rms})^2 Rt$

$mS\Delta T = (I_{rms})^2 Rt$

$t = \frac{mS\Delta T}{(I_{rms})^2 R} = \frac{2\times10}{(I_{rms})^2 100}$ ...(*i*)

$I_{rms} = \frac{20}{\sqrt{(X_L - X_C)^2 + R^2}}$, $X_L = 2\times\pi\times 750\times 1803$

$X_C = \frac{1}{2\times\pi\times750\times10^{-6}}$

Put value in (*i*), *t* come out ≈ 348 s

103. (c) $E = Pt$

$= \frac{E^2}{Z^2}Rt = \frac{(24)^2}{60^2 + (8.33\pi - 2\pi)^2}$

$(60)(60) = 518J.$

104. (a) The resonant frequency of *LC* oscillations is

$\omega_0 = \frac{1}{\sqrt{LC}}$

$\Rightarrow \omega = \frac{1}{\sqrt{2L\times8C}} = \frac{1}{4\sqrt{LC}}$

$\left[\because \begin{matrix} L' \to 2L \\ C' \to 8C \end{matrix}\right]$, $\omega = \frac{\omega_0}{4}$

$\Rightarrow x = \frac{1}{4}$

105. (a) Resonace depend upon the inductance and capacitance present in the circuit $f_r = \frac{1}{2\pi\sqrt{LC}}$. Also power factor is zero for pure inductor or pure capacitor hence both the component consume zero average power.

106. [9] $E_{inductor} = E_{capacitor}$

$\frac{1}{2}Li_{max}^2 = \frac{1}{2}\frac{Q_{max}^2}{C} \Rightarrow i_{max}^2 = \frac{Q_{max}^2}{LC}$

$i_{max} = \sqrt{\frac{1}{LC}}Q_{max}$

$= \frac{2.7\times10^{-6}}{\sqrt{75\times10^{-3}\times1.2\times10^{-6}}} = 9mA$

107. (b) Metal detector works on the principle of resonance in AC circuit.

108. [10] Given, $C = 500\mu F$, $V = 100v$, $L = 50mH$

In this *LC* – oscillation

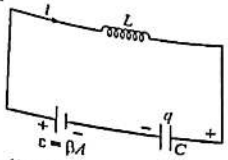
$q = q_0\cos\omega t$

$i = \frac{-dq}{dt} = q_0\omega\sin\omega t$

$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{50\times10^{-3}\times5\times10^{-4}}} = 200$

So, $i_{max} = q_0\omega = 500\times10^{-6}\times100\times200 = 10A$

109. [4]



$\phi = (B_0 + \beta t)A$

$|e_{ind}| = \frac{d\phi}{dt} = \beta A$

Applying *KVL* in the equivalent circuit diagram of the loop.

$\beta A - \frac{Ldi}{dt} - \frac{q}{C} = 0$ ...(*i*)

Also, $i = \frac{dq}{dt}$ ...(*ii*)

From (*i*) and (*ii*) $L\frac{d^2i}{dt^2} = -\frac{i}{C}$

$i = i_m\sin\omega t$, $\omega = \frac{1}{\sqrt{LC}}$

$\int_0^q dq = i_m\int_0^t \sin(\omega t)dt \Rightarrow q$

$= \frac{i_m}{\omega}(1 - \cos\omega t)$

When $i = i_m \Rightarrow \cos\omega t = 0$

$\therefore q = \frac{i_m}{\omega}$

Now, $i_m = \omega\beta AC = \frac{\beta AC}{\sqrt{LC}}$

$i_m = \frac{0.04\times1\times10^{-3}}{\sqrt{0.1\times10^{-3}}} = 4mA$

110. [400] $P = \frac{(250)^2}{Z}\cos\phi$ $500 = \frac{(250)^2}{Z}$

$Z = 125\ \Omega$

$R = 100\ \Omega$

$X_L = 75\ \Omega$

$75 = \frac{1}{2\pi fC}$

$C = \frac{1}{2\pi\times75\times50} = \frac{1}{7500\pi}$

$C = \left(\frac{10^6}{2500}\times\frac{1}{3\pi}\right)\mu F$

$C = \frac{400}{3\pi}\mu F$

111. (c) $\frac{N_1}{N_2} = \frac{V_1}{V_2} \Rightarrow \frac{230}{V_2} = \frac{10}{1}$

$\Rightarrow V_2 = 23V$

Therefore, Power consumed $= \frac{V_1^2}{R}$

$= \frac{23\times23}{46} = 11.5W$

112. (a) We know that, $\frac{\varepsilon_1}{\varepsilon_2} = \frac{N_1}{N_2}$

So, $\frac{\varepsilon_1}{\varepsilon_2} = \frac{N_1}{N_2} = \frac{100}{10} \Rightarrow \varepsilon_2 = 22$ V

Hence, $I = \frac{22}{22\times10^3} = 1$ mA,

and, $V_0 = 7$ V

113. (45) Given input power = 2.3kV

no. of turns in primary winding = 3000

Output power = 230V

Current in primary winding = 5A

efficiency = 90 %

$P_i = 2300\times5$ watt

$P_0 = 2300\times5\times0.9 = 230\times I_2$

output current of transformer is

$I_2 = 45A$

114. (b) Efficiency of a transformer,

$= \frac{E_s I_s}{E_P I_p}$

$\boxed{0.8 = \frac{240I_s}{\cdot4000}}$

$\boxed{I_S = \frac{3200}{240} = 13.33A}$

115. (d) Capacitance of the plates,

C = 200 pF

Angular frequency = 300 rad/s

$I = \frac{V}{X_C} = 230\times300\times200\times10^{-12} = 13.8\mu A$

116. (c) Based on theory.

117. [240] $V_p = 12\times10^3$ volts

$V_s = 120$ volts

From the formula of power, $I_s = \frac{P_s}{V_s}$

$I_s = \frac{60\times10^3}{120} = 5\times10^2\ A$

From ohmis low

$R_L = \frac{V_s}{I_s} = \frac{120}{5\times10^2} = 24\times10^{-2}$

$= 240\times10^{-3}\Omega$

$= 240\ m\Omega$

@EAKE_CBSE_X@RAJ_EAKET

118. (a) AC generator convert mechanical energy into electrical energy. Galvanometer detect current present in any wire.
Transformer is used to transform electrical energy from one AC circuit to another by reducing or increasing the voltage.

119. (c) Given: $V_p = 8\text{kV}$, $V_s = 160\text{v}$ P = 80kW (Purely resistive load)

$$P = VI = \frac{V_p^2}{R_p} = \frac{V_s^2}{R_s}$$

$$\Rightarrow R_p = \frac{V_p^2}{P} = \frac{(8\times10^3)^2}{80\times10^3} = 800\Omega$$

$$R_s = \frac{V_s^2}{P} = \frac{160\times160}{80\times10^3} = 0.32\Omega$$

120. (a) Fact based

121. (c) Power of secondary source $P_s = V_s \times i_s$

$$\Rightarrow V_s = \frac{P}{i_s} = \frac{60}{0.11} \approx 545\ V$$

$V_s > V_p$, the transformer is a step-up transformer.

122. [440] $\frac{N_p}{N_s} = \frac{V_p}{V_s} \Rightarrow N_p = \frac{V_p}{V_s} \times N_s$

$$= \frac{220}{12} \times 24 = 440$$

123. (c) Power equation of a transformer is given as

$e_1 i_1 \times \eta = e_2 i_2$

$\Rightarrow 2300 \times 5 \times \frac{90}{100} = 230 \times i_2$

$\Rightarrow i_2 = 45\ \text{A}$

124. (b) Given $N_p = 300, N_s = 150, P_0 = 2200\ \text{W}$

$I_s = 10\text{A}$

$P_0 = V_0 I_0 = 2200 \Rightarrow V_0 = 220\ \text{V}$

Using transformer equation, we have

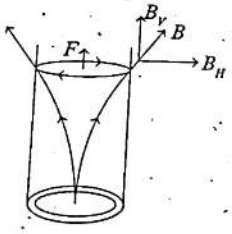
$\because \frac{V_i}{V_0} = \frac{N_p}{N_s} \Rightarrow V_i = 2 \times 220 = 440\ \text{V}$

Also for no loss in transformer, we use $P_i = P_0 = V_i I_i$

$\Rightarrow I_i = \frac{2200}{440} = 5\ \text{A}$

JEE-Advanced

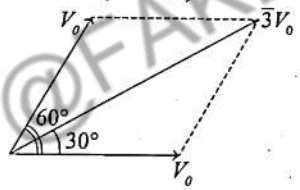
1. (a) The induced current in the ring will interact with horizontal component of magnetic field and both will repel each other. This repulsion will balance the weight of ring.



Hence, option (a) is correct.

2. (b, c) $V_{xy} = V_x - V_y = V_0 \sin\left(\omega t + \frac{2\pi}{3}\right) - V_0 \sin \omega t$

$= V_0 \sin\left(\omega t + \frac{2\pi}{3}\right) + V_0 \sin(\omega t + \pi)$



$\Rightarrow \phi = \pi - \frac{2\pi}{3} = \frac{\pi}{3}$

$\Rightarrow V_{xy} = \sqrt{3}V_0 \sin(\omega t + 30°)$

Therefore, $(V_{xy})_{rms} = \frac{\sqrt{3}V_0}{\sqrt{2}}$

Similarly we can find $(V_{yz})_{rms}$

3. [6] Take the circular tube as a long solenoid. The wires are closely wound. Magnetic field inside the solenoid is

$B = \mu_0 ni$

Here, n = number of turns per unit length

$\therefore$ ni = current per unit length

In the given problem $ni = \frac{I}{L}$

$\therefore$ $B = \frac{\mu_0 I}{L}$

Flux passing through the circular coil is

$\phi = BS = \left(\frac{\mu_0 I}{L}\right)(\pi r^2)$

Induced emf $e = -\frac{d\phi}{dt} = -\left(\frac{\mu_0 \pi r^2}{L}\right)\cdot\frac{dI}{dt}$

Induced current, $i = \frac{e}{R} = -\left(\frac{\mu_0 \pi r^2}{LR}\right)\cdot\frac{dI}{dt}$

Magnetic moment, $M = iA = i\pi r^2$

or $M = -\left(\frac{\mu_0 \pi^2 r^4}{LR}\cdot\frac{dI}{dt}\right)$ ...(i)

Given, $I = I_0 \cos(300t)$

$\therefore$ $\frac{dI}{dt} = -300 I_0 \sin(300t)$

Substituting in Eq. (i), we get

$M = \left(\frac{300\pi^2 r^4}{LR}\right)\mu_0 I_0 \sin(300t)$

$\therefore$ $N = \frac{300\pi^2 r^4}{LR}$

Substituting the values, we get

$N = \frac{300\pi^2 r^4}{LR} = 5.926$ or N = 6

4. Outside the solenoid, net magnetic field is zero. It can be assumed only inside the solenoid and equal to $\mu_0 nI$.

Induced $e = \frac{d\phi}{dt} = -\frac{d}{dt}(\mu_0 nI \pi a^2)$

or $|e| = (\mu_0 n \pi a^2)(I_0 \omega \cos \omega t)$

Resistance of the cylindrical vessel

$= \frac{\rho l}{A} = \frac{\rho(2\pi R)}{Ld}$

$\therefore$ Induced current, $i = \frac{|e|}{R}$

$= \frac{\mu_0 L d n a^2 I_0 \omega \cos \omega t}{2\rho R}$

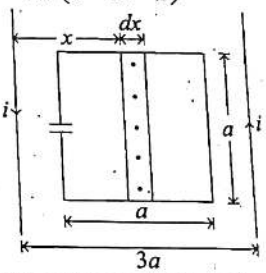
Note: Here current in cylindrical shell is in circular path.

$\therefore$ In resistance $= \frac{\rho l}{A}$, $l = 2\pi R$ and $A = Ld$

5. (a) For an elemental strip of thickness dx at a distance x from left wire, net magnetic field (due to both wires)

$B = \frac{\mu_0}{2\pi}\frac{I}{x} + \frac{\mu_0}{2\pi}\frac{I}{3a-x}$ (outwards)

$= \frac{\mu_0 I}{2\pi}\left(\frac{1}{x} + \frac{1}{3a-x}\right)$



Magnetic flux in this strip,

$d\phi = BdS = = \frac{\mu_0 I}{2\pi}\left(\frac{1}{x} + \frac{1}{3a-x}\right)a\,dx$

$\therefore$ Total flux,

$\phi = \int_a^{2a} d\phi = \frac{\mu_0 Ia}{2\pi}\int_a^{2a}\left(\frac{1}{x} + \frac{1}{3a-x}\right)dx$

@FAKE_CBSE_X_@RAJ_FB.NET

$\Rightarrow i_2 = 45\ A$

(b) Given $N_p = 300, N_s = 150, P_o = 2200\ W$
$= 10A$

$= V_0 I_0 = 2200 \Rightarrow V_0 = 220\ V$
ng transformer equation, we have
$\frac{V_i}{V_0} = \frac{N_p}{N_s} \Rightarrow V_i = 2 \times 220 = 440\ V$
for no loss in transformer, we use
$P_0 = V_i I_i$

$\frac{2200}{440} = 5\ A$

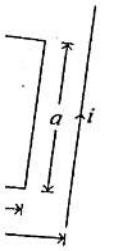
$\pi a^2)(I_0\omega \cos \omega t)$
of the cylindrical vessel
$\frac{\pi R)}{d}$

urrent, $i = \frac{|e|}{R}$
$\cos \omega t$

ent in cylindrical shell is in
$= \frac{\rho l}{A}$, $l = 2\pi R$ and

al strip of thickness dx at
m left wire, net magnetic
th wires)
$\frac{I}{3a-x}$ (outwards)

$\frac{}{x}\Big)$



strip,
$+\frac{1}{3a-x}\Big) a\,dx$

$\frac{1}{3a-x}\Big) dx$

$\phi = \frac{\mu_0 Ia}{\pi} In(2)$

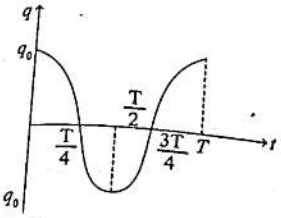
$\phi = \frac{\mu_0 aIn(2)}{\pi}(I_0 \sin \omega t)$ ...(i)

Magnitude of induced emf,
$e = \left|\frac{d\phi}{dt}\right| = \frac{\mu_0 aI_0 \omega In(2)}{\pi} \cos \omega t$
$= e_0 \cos \omega t$
where, $e_0 = \frac{\mu_0 aI_0 \omega In(2)}{\pi}$

Charge stored in the capacitor,
$q = Ce = Ce_0 \cos \omega t$ ...(ii)
and current in the loop
$i = \frac{dq}{dt} = C\omega e_0 \cos \omega t$ ...(iii)

$i_{max} = C\omega e_0 = \frac{\mu_0 aI_0 \omega^2 C \ln(2)}{\pi}$

(b) Magnetic flux passing through the square loop



$\phi \propto \sin \omega t$. [From Eq. (i)]
i.e. $\odot$ u magnetic field passing through the loop is increasing at $t = 0$. Hence, the induced current will produce $\otimes$ magnetic field (from Lenz's law). Or the current in the circuit at $t = 0$ will be clockwise (or negative as per the given convention). Therefore, charge on upper plate could be written as,
$q = +q_0 \cos \omega t$ [From Eq. (ii)]
Here, $q_0 = Ce_0 = \frac{\mu_0 aCI_0 \omega \ln(2)}{\pi}$

The corresponding q-t graph is shown in figures

6. (a) As the current i leads the emf e by $\pi/4$, it is an R-C circuit.

$\tan \phi = \frac{X_C}{R} \Rightarrow \tan \frac{\pi}{4} = \frac{\frac{1}{\omega C}}{R}$

$\therefore \omega CR = 1$
As $\omega = 100$ rad/s

The product of C-R should be $\frac{1}{100} s^{-1}$

7. (c, d) $\frac{dQ}{dt} = I$

$\Rightarrow Q = \int I\,dt = \int (I_0 \cos \omega t)\,dt$

$\therefore Q_{max} = \frac{I_0}{\omega} = \frac{1}{500} = 2 \times 10^{-3} C$

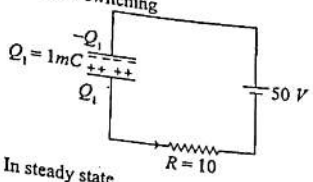
At $t = \frac{7\pi}{6\omega}$ or $\omega t = \frac{7\pi}{6}$

Current comes out to be negative from the given expression.
So, current is anti-clockwise. Charge supplied by source from $t = 0$ to $t = \frac{7\pi}{6\omega}$

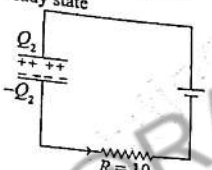
$Q = \int_0^{\frac{7\pi}{6\omega}} \cos(500t)\,dt$

$= \left[\frac{\sin 500t}{500}\right]_0^{\frac{7\pi}{6\omega}} = \frac{\sin \frac{7\pi}{6}}{500} = -1mC$

Just after switching



In steady state



Apply Kirchhoff's loop law, just after changing the switch to position D
$50 + \frac{Q_1}{C} - IR = 0$

Substituting the values of Q_1, C and R, we get
$I = 10\ A$

In steady state $Q_2 = CV = 1mC$
$\therefore$ Net charge flown from battery $= 2\ mC$

8. (b, c) $Z = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$

In case (B), capacitance C will be more. Therefore, impedence Z will be less. Hence, current will be more.

Further, $V_C = IX_C = \left(\frac{V}{Z}\right) X_C$

$= \frac{V}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}} \left[\frac{1}{\omega C}\right] = \frac{V}{\sqrt{1 + (\omega CR)^2}}$

Now, in case (B) value of C increase, So VC decreases.

9. (A) $\rightarrow$ r, s, t; (B) $\rightarrow$ q, r, s, t; (C) $\rightarrow$ q, p; (D) $\rightarrow$ q, r, s, t
In circuit (p): I can't be non zero in steady state.
In circuit (q): $V_1 = 0$ and $V_2 = 2I = V$ (also)
In circuit (r): $V_1 = X_L I = (2\pi fL) I$
$= (2\pi \times 50 \times 6 \times 10^{-3}) I = 1.88I$
$V_2 = 2I$
In circuit (s): $V_1 = X_L I = 1.88I$
$V_2 = X_C I = \left(\frac{1}{2\pi fC}\right) I$
$= \left(\frac{1}{2\pi \times 50 \times 3 \times 10^{-6}}\right) I = (1061) I$
In circuit (t):
$V_1 = IR = (1000) I$
$V_2 = X_C I = (1061) I$

10. (a, b) At $\omega \approx 0$, $X_C = \frac{1}{\omega C} = \infty$. Therefore, current is nearly zero.
Further at resonance frequency, current and voltage are in phase. This resonance frequency is given by
$\omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{10^{-6} \times 10^{-6}}} = 10^6\ rad/s$
We can see that this frequency is independent of R.

Further, $X_L = \omega_L, X_C = \frac{1}{\omega C}$
At, $\omega = \omega_r = 10^6$ rad/s, $X_L = X_C$
For $\omega > \omega_r, X_L > X_C$. So, circuit is inductive.

11. (b) Given, $V = 45 \sin \omega t$, $L = 50$ mH, $\omega_0 = 10^5$ rad/s
$\omega = 8 \times 10^4$ rad/s $= 0.8\ \omega_0$
Resonance frequency of L–C–R circuit,

$\omega_0 = \frac{1}{\sqrt{LC}}$

$\therefore C = \frac{1}{L\omega_0^2} = \frac{1}{5 \times 10^{-2} \times 10^{10}}$
$= 2 \times 10^{-9}\ F$

$I = 0.05 I_0 = \frac{I_0}{20} \Rightarrow Z = 20R$

$X_L = \omega L = 8 \times 10^4 \times 5 \times 10^{-2} \Omega = 4k\Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{8 \times 10^4 \times 2 \times 10^{-9}} = \frac{25}{4} k\Omega$

Impedance of the circuit,
$Z^2 = R^2 + (X_C - X_L)^2$

$400R^2 = R^2 + \left(\frac{9}{4} k\Omega\right)^2$

$R = \frac{\frac{9}{4} k\Omega}{\sqrt{399}} \approx \frac{9}{80} k\Omega = \frac{900}{8} \Omega$

Current amplitude,

$I_0 = \frac{V_0}{R} = \frac{45 \times 8}{900} = \frac{8}{20} A \approx 0.4A$
$= 400$ mA

Quality factor,

@FAKE_CODE_KRAJ_EDUNET

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{8}{900}\sqrt{\frac{5\times10^{-2}}{2\times10^{-9}}}$$

$$= \frac{8}{900}\sqrt{25\times10^{6}} = 44.4$$

Also, $Q = \frac{\omega_0}{\Delta\omega}$

Therefore bandwidth,

$$\Delta\omega = \frac{\omega_0}{Q} = \frac{10^3}{44.4} = 2250.0$$

Maximum power dissipated

$$P_{max} = I_0^2 R = \frac{45^2}{R^2}\times R = \frac{45^2}{R}$$

$$= \frac{45^2}{900}\times 8 = 18.4W$$

12. (*b*) Impedance, $Z = \sqrt{R^2 + X_c^2}$, $I_{rms} = \frac{V_{rms}}{Z}$, $P = I_{rms}^2 R$

Where, $X_C = \frac{1}{\omega C}$

As ω is increased, X_C will be decrease or Z will be decrease.

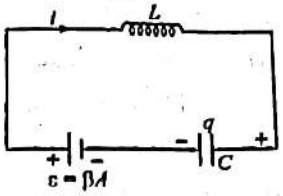
Hence, I_{rms} or P will increase. Therefore, bulb glows brighter.

13. (*d*) From conservation of energy,

$$\frac{1}{2}LI_{max}^2 = \frac{1}{2}CV^2$$

$$\therefore I_{max} = V\sqrt{\frac{C}{L}}$$

14. [4]



$\varepsilon = \beta A$

$\phi = (B_0 + \beta t)A$

$|\varepsilon_{ind}| = \frac{d\phi}{dt} = \beta A$

Applying *KVL* in the equivalent circuit diagram of the loop.

$$\beta A - \frac{Ldi}{dt} - \frac{q}{C} = 0 \qquad ...(i)$$

Also, $i = \frac{dq}{dt}$ ...(*ii*)

From (*i*) and (*ii*) $L\frac{d^2i}{dt^2} = -\frac{i}{C}$

$i = i_m \sin\omega t$

$$\omega = \frac{1}{\sqrt{LC}}$$

$$\int_0^q dq = i_m\int_0^t \sin(\omega t)dt$$

$$\Rightarrow q = \frac{I_m}{\omega}(1-\cos\omega t)$$

When $i = I_m \Rightarrow \cos\omega t = 0$

$\therefore q = \frac{I_m}{\omega}$

Now, $I_m = \omega\beta AC = \frac{\beta AC}{\sqrt{LC}}$

$$I_m = \frac{0.04\times1\times10^{-3}}{\sqrt{0.1\times10^{-3}}} = 4mA$$

15. (*b*) $P = VI$

$$\therefore I = \frac{P}{V} = \frac{600\times10^3}{4000} = 150A$$

Total resistance of cables, $R = 0.4\times20 = 8\Omega$

$\therefore$ Power loss in cables $= I^2R$

$= (150)^2(8)$

$= 180000\ W = 180\ kW$

This loss is 30% of 600 kW.

16. (*a*) During step-up, $\frac{N_P}{N_S} = \frac{V_P}{V_S}$

or $\frac{1}{10} = \frac{4000}{V_S}$

or $V_S = 40000\ V$

In step down transformer,

$$\frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{40000}{200} = \frac{200}{1}$$

@FAKE_CBSE X @RAJ EDUNET

24 Electromagnetic Waves

Scan for Sol

JEE-Main

Displacement Current and Properties of EM Wave

1. An alternating voltage of amplitude 40 V and frequency 4 kHz is applied directly across the capacitor of 12 μF. The maximum displacement current between the plates of the capacitor is nearly: **[05 April, 2024 (Shift-I)]**
   (a) 13 A (b) 8 A
   (c) 10 A (d) 12 A

2. If $\vec{E}$ and $\vec{K}$ represent electric field and propagation vectors of the EM waves in vacuum, then magnetic field vector is given by: (ω – angular frequency): **[24 Jan, 2023 (Shift-I)]**
   (a) $\frac{1}{\omega}\left(\vec{K}\times\vec{E}\right)$ (b) $\omega\left(\vec{E}\times\vec{K}\right)$
   (c) $\omega\left(\vec{K}\times\vec{E}\right)$ (d) $\vec{K}\times\vec{E}$

3. All electromagnetic wave is transporting energy in the negative z direction. At a certain point and certain time the direction of electric field of the wave is along positive y direction. What will be the direction of the magnetic field of the wave at that point and at that instant? **[25 Jan, 2023 (Shift-I)]**
   (a) Positive direction of x (b) Positive direction of z
   (c) Negative direction of x (d) Negative direction of y

4. The displacement current of 4.425 μA is developed in the space between the plates of parallel plate capacitor when voltage is changing at a rate of 10^6 Vs^{-1}. The area of each plate of the capacitor is 40 cm^2. The distance between each plate of the capacitor is $x \times 10^{-3}$ m. The value of x is, _____ (Permittivity of free space, $\epsilon_0 = 8.85\times10^{-12}$ $C^2N^{-1}m^{-2}$) **[29 June, 2022 (Shift-II)]**

5. Identify the correct statements from the following descriptions of various properties of electromagnetic waves.
   (A) In a plane electromagnetic wave electric field and magnetic field must be perpendicular to each other and direction of propagation of wave should be along electric field or magnetic field.
   (B) The energy in electromagnetic wave is divided equally between electric and magnetic fields.
   (C) Both electric field and magnetic filed are parallel to each other and perpendicular to the direction of propagation of wave.
   (D) The electric field, magnetic field and direction of propagation of wave must be perpendicular to each other.
   (E) The ratio of amplitude of magnetic field to the amplitude of electric field is equal to speed of light.
   Choose the most appropriate answer from the options given below: **[27 July, 2022 (Shift-II)]**
   (a) (D) only (b) (B) and (D) only
   (c) (B), (D) and (E) only (d) (A), (B) and (E) only

6. An EM wave propagating in x-direction has a wavelength of 8 mm. The electric field vibrating y-direction has maximum magnitude of 60 Vm^{-1}. Choose the correct equations for electric and magnetic field if the EM wave if propagating in vacuum **[28 June, 2022 (Shift-II)]**

   (a) $E_y = 60\sin\left[\frac{\pi}{4}\times10^3(x-3\times10^8t)\right]\hat{j}\,Vm^{-1}$
   $B_z = 2\sin\left[\frac{\pi}{4}\times10^3(x-3\times10^8t)\right]\hat{k}T$

   (b) $E_y = 60\sin\left[\frac{\pi}{4}\times10^3(x-3\times10^8t)\right]\hat{j}\,Vm^{-1}$
   $B_z = 2\times10^{-7}\sin\left[\frac{\pi}{4}\times10^3(x-3\times10^8t)\right]\hat{k}T$

   (c) $E_y = 2\times10^{-7}\sin\left[\frac{\pi}{4}\times10^3(x-3\times10^8t)\right]\hat{j}\,Vm^{-1}$
   $B_z = 60\sin\left[\frac{\pi}{4}\times10^3(x-3\times10^8t)\right]\hat{k}T$

   (d) $E_y = 2\times10^{-7}\sin\left[\frac{\pi}{4}\times10^4(x-4\times10^8t)\right]\hat{j}\,Vm^{-1}$
   $B_z = 60\sin\left[\frac{\pi}{4}\times10^4(x-4\times10^8t)\right]\hat{k}T$

7. Given below are two statements:
   Statement-I: A time varying electric field is a source of changing magnetic field and vice-versa.
   Thus a disturbance in electric or magnetic field creates EM waves.
   Statement-II: In a material medium, the EM wave travels with speed $v = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$.
   In the light of the above statements, choose the correct answer from the options given below **[27 June, 2022 (Shift-II)]**
   (a) Both Statement-I and Statement-II are true.
   (b) Both Statement-I and Statement-II are false.
   (c) Statement-I is correct but Statement-II are false.
   (d) Statement-I is incorrect but Statement-II is true.

@FREE_CBSE_RA_EDUNIT

8. If Electric field intensity of a uniform plane electro magnetic wave is given as

$$E = -301.6\sin(kz-\omega t)\hat{a}_x + 452.4\sin(kz-\omega t)\hat{a}_y \frac{V}{m}$$

Then, magnetic intensity H of this wave in Am^{-1} will be:

[Given: Speed of light in vaccum $\mu_0 = 4\pi\times10^{-7}\ NA^{-2}$, Permeability of vacuum] **[26 June, 2022 (Shift-I)]**

(a) $+0.8\sin(kz-\omega t)\hat{a}_y + 0.8\sin(kz-\omega t)\hat{a}_x$

(b) $+1.0\times10^{-6}\sin(kz-\omega t)\hat{a}_y + 1.5\times10^{-6}(kz-\omega t)\hat{a}_x$

(c) $-0.8\sin(kz-\omega t)\hat{a}_y - 1.2\sin(kz-\omega t)\hat{a}_x$

(d) $-1.0\times10^{-6}\sin(kz-\omega t)\hat{a}_y - 1.5\times10^{-6}\sin(kz-\omega t)\hat{a}_x$

9. Electric field of a plane electromagnetic wave propagating through a non-magnetic medium is given by $E = 20\cos(2\times10^{10}t - 200x)$ V/m. The dielectric constant of the medium is equal to:

(Take $\mu_r = 1$) **[1 Sept, 2021 (Shift-II)]**

(a) $\frac{1}{3}$ (b) 3 (c) 2 (d) 9

10. AC voltage $V(t) = 20\sin\omega t$ of frequency 50Hz is applied to a parallel plate capacitor. The separation between the plates is 2mm and the area is $1m^2$. The amplitude of the oscillating displacement current for the applied AC voltage is _____. [Take $\varepsilon_0 = 8.85\times10^{-12}$ F/m] **[20 July, 2021 (Shift-I)]**

(a) 83.37 μA (b) 55.58 μA

(c) 21.14 μA (d) 27.79 μA

11. Sea-water at a frequency $f = 9\times10^2$ Hz, has permittivity $\varepsilon = 80\varepsilon_0$ and resistivity $\rho = 0.25\Omega$m. Imagine a parallel plate capacitor is immersed in seawater and is driven by an alternating voltage source $V(t) = V_0\sin(2\pi ft)$. Then the conduction current density become 10^x times the displacement current density after time $t = \frac{1}{800}s$. The value of x is ____ **[17 March, 2021 (Shift-II)]**

$$\left(\text{Given}: \frac{1}{4\pi\varepsilon_0} = 9\times10^9 Nm^2C^{-2}\right)$$

12. A linearly polarized electromagnetic wave in vacuum is $E = 3.1\cos[(1.8)z-(5.4\times10^6)t]\hat{i}\,N/C$ Is incident normally on a perfectly reflecting wall at $z = a$. Choose the correct option **[25 July, 2021 (Shift-I)]**

(a) The frequency of electromagnetic wave is 54×10^4 Hz.

(b) The transmitted wave will be

$3.1\cos[(1.8)z-(5.4\times10^6)t]\hat{i}\,N/C$

(c) The reflected wave will be

$3.1\cos[(1.8)z+(5.4\times10^6)t]\hat{i}\,N/C$

(d) The wavelength is 5.4 m

13. In an electromagnetic wave the electric field vector and magnetic field vector are given as $\vec{E} = E_0\hat{i}$ and $\vec{B} = B_0\hat{k}$ respectively. The direction of propagation of electromagnetic wave is along. **[20 July, 2021 (Shift-II)]**

(a) $(-\hat{k})$ (b) $(\hat{k})$ (c) $(-\hat{j})$ (d) $\hat{j}$

14. Electric field in a plane electromagnetic wave is given by $E = 50\sin(500x - 10\times10^{10}t)$ V/m **[27 Aug, 2021 (Shift-I)]**

The velocity of electromagnetic wave in this medium is: (Given c = speed of light in vacuum)

(a) c (b) $\frac{c}{2}$ (c) $\frac{2}{3}c$ (d) $\frac{3}{2}c$

15. An electromagnetic wave of frequency 3 GHz enters a dielectric medium of relative electric permittivity 2.25 from vacuum. The wavelength of this wave in that medium will be _____ $\times10^{-1}$ cm. **[24 Feb, 2021 (Shift-II)]**

16. An electromagnetic wave of frequency 5 GHz, is travelling in a medium whose relative electric permittivity and relative magnetic permeability both are 2. Its velocity in the this medium is ____ $\times10^7$ m/s. **[24 Feb, 2021 (Shift-I)]**

17. A plane electromagnetic wave is propagating along the direction $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$, with its polarization along the direction $\hat{k}$. The correct form of the magnetic field of wave would be (here B_0 is an appropriate constant) **[9 Jan, 2020 (Shift-II)]**

(a) $B_0\frac{\hat{i}+\hat{j}}{\sqrt{2}}\cos\left(\omega t - k\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

(b) $B_0\frac{\hat{i}-\hat{j}}{\sqrt{2}}\cos\left(\omega t + k\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

(c) $B_0\frac{\hat{i}-\hat{j}}{\sqrt{2}}\cos\left(\omega t - k\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

(d) $B_0\hat{k}\cos\left(\omega t - k\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

18. The electric field of a plane electromagnetic wave is given by **[7 Jan, 2020 (Shift-II)]**

$$\vec{E} = E_0\frac{\hat{i}+\hat{j}}{\sqrt{2}}\cos(kz+\omega t)$$

At $t = 0$, a positively charged particle is at the point $(x,y,z) = \left(0,0,\frac{\pi}{k}\right)$.

If its instantaneous velocity at $(t = 0)$ is $v_0\hat{k}$, the force acting on it due to the wave is:

(a) zero (b) parallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

(c) parallel to $\hat{k}$ (d) antiparallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

19. A plane electromagnetic wave having a frequency $\nu = 23.9$ GHz propagates along the positive z-direction in free space. The peak value of the electric field is 60 V/m. Which among the following is the acceptable magnetic field component in the electromagnetic wave? **[12 April, 2019 (Shift-II)]**

(a) $\vec{B} = 2\times10^7\sin\left(0.5\times10^3 z + 1.5\times10^{11}t\right)\hat{i}$

(b) $\vec{B} = 2\times10^{-7}\sin\left(1.5\times10^2 x + 0.5\times10^{11}t\right)\hat{j}$

(c) $\vec{B} = 2\times10^{-7}\sin\left(0.5\times10^3 z - 1.5\times10^{11}t\right)\hat{i}$

(d) $\vec{B} = 60\sin\left(0.5\times10^3 x + 1.5\times10^{11}t\right)\hat{k}$

@FAKE_CBSE_K @RAJEEDUNET

wave in this medium is: [Aug, 2021 (Shift-I)]

(a) $\frac{2}{3}c$ (d) $\frac{3}{2}c$

iency 3 GHz enters a dielectric ttivity 2.25 from vacuum. The edium will be [24 Feb, 2021 (Shift-II)]

ncy 5 GHz, is travelling in a nittivity and relative magnetic in the this medium is [24 Feb, 2021 (Shift-I)]

pagating along the direction irection $\hat{k}$. The correct form e (here B_0 is an appropriate [9 Jan, 2020 (Shift-II)]

wave is given by Jan, 2020 (Shift-II)]

$(x, y, z) = \left(0, 0, \frac{\pi}{k}\right)$.

he force acting on it

$\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

a frequency direction in free m. Which among component in the 2019 (Shift-II)]

An electromagnetic wave is represented by the electric field $\vec{E} = E_0\hat{n}\sin[\omega t + (6y - 8z)]$. Taking unit vectors in x, y and z directions to be $\hat{i}, \hat{j}, \hat{k}$, the direction of propagation $\hat{s}$ is [12 April, 2019 (Shift-I)]

(a) $\hat{s} = \left(\frac{4\hat{j} - 3\hat{k}}{5}\right)$ (b) $\hat{s} = \left(\frac{-3\hat{j} - 4\hat{j}}{5}\right)$

(c) $\hat{s} = \left(\frac{-3\hat{j} + 4\hat{k}}{5}\right)$ (d) $\hat{s} = \left(\frac{-4\hat{k} + 3\hat{j}}{5}\right)$

Maxwell's Equations & Magnetic Field Between Parallel Plate Capacitor

21. Match List-I with List-II. [29 Jan, 2024 (Shift-I)]

	List-I		List-II
A.	$\oint \vec{B}\cdot d\vec{l} = \mu_0 i_c + \mu_0\epsilon_0 \frac{d\phi_E}{dt}$	I.	Gauss' law for electricity
B.	$\oint \vec{E}\cdot d\vec{l} = \frac{d\phi_B}{dt}$	II.	Gauss' law for magnetism
C.	$\oint \vec{E}\cdot d\vec{A} = \frac{Q}{\epsilon_0}$	III.	Faraday law
D.	$\oint \vec{B}\cdot d\vec{A} = 0$	IV.	Ampere-Maxwell law

Chose the correct answer from the options given below:

(a) A-IV, B-I, C-III, D-II

(b) A-II, B-III, C-I, D-IV

(c) A-IV, B-III, C-I, D-II

(d) A-IV, B-II, C-III, D-IV

22. Which of the following Maxwell's equations is valid for time varying conditions but not valid for static conditions: [13 Apr 2023 (Shift-I)]

(a) $\oint \vec{B}\cdot d\vec{l} = \mu_0 I$ (b) $\oint \vec{E}\cdot d\vec{l} = 0$

(c) $\oint \vec{E}\cdot d\vec{l} = -\frac{\partial\phi_B}{\partial t}$ (d) $\oint \vec{D}\cdot d\vec{A} = Q$

23. Match List-I with List-II: [25 Jan 2023 (Shift-II)]

A.	Gauss's Law in Electrostatics	I.	$\oint \vec{E}\cdot d\vec{l} = -\frac{d\phi_B}{dt}$
B.	Faraday's Law	II.	$\oint \vec{B}\cdot d\vec{A} = 0$
C.	Gauss's Law in Magnetism	III.	$\oint \vec{B}\cdot\vec{l} = \mu_0 i_C + \mu_0\epsilon_0 \frac{d\phi_E}{dt}$
D.	Ampere Maxwell Law	IV.	$\oint \vec{E}\cdot\vec{s} = \frac{q}{\epsilon_0}$

Choose the correct answer from the options given below:

(a) A-IV, B-I, C-II, D-III (b) A-I, B-II, C-III, D-IV

(c) A-III, B-IV, C-I, D-II (d) A-II, B-III, C-IV, D-I

24. The material filled between the plates of a parallel plate capacitor has resistivity 200Ωm. The value of capacitance of the capacitor is 2pF. If a potential difference of 40 V is applied across the plates of the capacitor, then the value of leakage current flowing out of the capacitor is : (given the value of relative permitivity of material is 50) [26 Aug, 2021 (Shift-I)]

(a) 0.9μA (b) 9.0mA (c) 9.0μA (d) 0.9mA

Wave Equation for EM Waves

25. The electric field in an electromagnetic wave is given by $\vec{E} = \hat{i}\,40\cos\omega\left(t - \frac{z}{c}\right)NC^{-1}$. The magnetic field induction of this wave is (in SI unit): [04 April, 2024 (Shift-I)]

(a) $\vec{B} = \hat{i}\frac{40}{c}\cos\omega\left(t - \frac{z}{c}\right)$

(b) $\vec{B} = \hat{j}\,40\cos\omega\left(t - \frac{z}{c}\right)$

(c) $\vec{B} = \hat{k}\frac{40}{c}\cos\omega\left(t - \frac{z}{c}\right)$

(d) $\vec{B} = \hat{j}\frac{40}{c}\cos\omega\left(t - \frac{z}{c}\right)$

26. In the given electromagnetic wave $E_y = 600\sin(\omega t - kx)\ Vm^{-1}$, intensity of the associated light beam is (in W/m^2): (Given $\epsilon_0 = 9\times10^{-11}C^2N^{-1}m^{-2}$) [06 April, 2024 (Shift-II)]

(a) 486 (b) 243

(c) 729 (d) 972

27. A plane EM wave is propagating along x direction. It has a wavelength of 4 mm. If electric field is in y direction with the maximum magnitude of 60 Vm^{-1}, the equation for magnetic field is: [09 April, 2024 (Shift-I)]

(a) $B_z = 60\sin\left[\frac{\pi}{2}(x - 3\times10^8 t)\right]\hat{k}T$

(b) $B_z = 2\times10^{-7}\left[\frac{\pi}{2}\times10^3(x - 3\times10^8 t)\right]\hat{k}T$

(c) $B_z = 60\sin\left[\frac{\pi}{2}(x - 3\times10^8 t)\right]\hat{k}T$

(d) $B_z = 2\times10^{-7}\sin\left[\frac{\pi}{2}(x - 3\times10^8 t)\right]\hat{k}T$

28. The magnetic field in a plane electromagnetic wave is $B_y = (3.5\times10^{-7})\sin(1.5\times10^3 x + 0.5\times10^{11}t)T$. The corresponding electric field will be [09 April, 2024 (Shift-II)]

(a) $E_y = 1.17\sin(1.5\times10^3 x + 0.5\times10^{11}t)Vm^{-1}$

(b) $E_y = 105\sin(1.5\times10^3 x + 0.5\times10^{11}t)Vm^{-1}$

(c) $E_z = 1.17\sin(1.5\times10^3 x + 0.5\times10^{11}t)Vm^{-1}$

(d) $E_y = 10.5\sin(1.5\times10^3 x + 0.5\times10^{11}t)Vm^{-1}$

@FAKE_CBSE_X @RAJEDUNET

29. A plane electromagnetic wave propagating in x-direction is described by [27 Jan, 2024 (Shift-I)]
$E_y = (200\ \text{Vm}^{-1})\sin[1.5\times10^7 t - 0.05x]$;
The intensity of the wave is:
(Use $\epsilon_0 = 8.85\times10^{-12}\ \text{C}^2\text{N}^{-1}\text{m}^{-2}$)
(a) 35.4 Wm^{-2} (b) 53.1 Wm^{-2}
(c) 26.6 Wm^{-2} (d) 106.2 Wm^{-2}

30. A plane electromagnetic wave of frequency 35 MHz travels in free space along the X-direction. At a particular point (in space and time) $\vec{E} = 9.6\hat{j}$ V/m. The value of magnetic field at this point is: [29 Jan, 2024 (Shift-II)]
(a) $3.2\times10^{-8}\hat{k}$ T (b) $3.2\times10^{-8}\hat{i}$ T
(c) $9.6\hat{j}$ T (d) $9.6\times10^{-8}\hat{k}$ T

31. The electric field of an electromagnetic wave in free space is represented as $\vec{E} = E_0\cos(\omega t - kz)\hat{i}$. The corresponding magnetic induction vector will be: [30 Jan, 2024 (Shift-I)]
(a) $\vec{B} = E_0 C\cos(\omega t - kz)\hat{j}$ (b) $\vec{B} = \frac{E_0}{C}\cos(\omega t - kz)\hat{j}$
(c) $\vec{B} = E_0 C\cos(\omega t + kz)\hat{j}$ (d) $\vec{B} = \frac{E_0}{C}\cos(\omega t + kz)\hat{j}$

32. If frequency of electromagnetic wave is 60 MHz and it travels in air along z direction then the corresponding electric and magnetic field vectors will be mutually perpendicular to each other and the wavelength of the wave (in m) is: [1 Feb, 2024 (Shift-II)]
(a) 2.5 (b) 10 (c) 5 (d) 2

33. A plane electromagnetic wave of frequency 20 MHz propagates in free space along x-direction. At a particular space and time, $\vec{E} = 6.6\hat{j}V/m$. What is $\vec{B}$ at this point? [11 April, 2023 (Shift-II)]
(a) $-2.2\times10^{-8}\hat{i}T$ (b) $2.2\times10^{-8}\hat{k}T$
(c) $-2.2\times10^{-8}\hat{k}T$ (d) $2.2\times10^{-8}\hat{i}T$

34. The amplitude of magnetic field in an electromagnetic wave propagating along y-axis is 6.0×10^{-7} T. The maximum value of electric field in the electromagnetic wave is: [10 April, 2023 (Shift-II)]
(a) 5×10^{14} Vm^{-1} (b) 180 Vm^{-1}
(c) 2×10^{15} Vm^{-1} (d) 6.0×10^{-7} Vm^{-1}

35. The electric field and magnetic field components of an electromagnetic wave going through vacuum is described by [24 Jan, 2023 (Shift-II)]
$E_x = E_0\sin(kz-\omega t)$
$B_y = B_0\sin(kz-\omega t)$
Then the correct relation between E_0 and B_0 is given by
(a) $kE_0 = \omega B_0$ (b) $E_0 B_0 = \omega k$
(c) $\omega E_0 = kB_0$ (d) $E_0 = kB_0$

36. Given below are two statements:
Statement-I: Electromagnetic waves are not deflected by electric and magnetic field.
Statement-II: The amplitude of electric field and the magnetic field in electromagnetic waves are related to each other as $E_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}B_0$
In the light of the above statements, choose the correct answer from the options given below: [29 Jan, 2023 (Shift-II)]
(a) Statement-I is true but Statement-II is false
(b) Both Statement-I and Statement-II are true
(c) Statement-I is false but Statement-II is true
(d) Both Statement-I and Statement-II are false

37. The electric field associated with an electromagnetic wave propagating in a dielectric medium is given by $\vec{E} = 30(2\hat{x}+\hat{y})\sin\left[2\pi\left(5\times10^{14}t - \frac{10^7}{3}z\right)\right]Vm^{-1}$. Which of the following option(s) is(are) correct?
[Given: The speed of light in vacuum, $c = 3\times10^8\ \text{ms}^{-1}$] [JEE Adv, 2023]
(a) $B_x = -2\times10^{-7}\sin\left[2\pi\left(5\times10^{14}t - \frac{10^7}{3}z\right)\right]\text{Wbm}^{-2}$
(b) $B_y = 2\times10^{-7}\sin\left[2\pi\left(5\times10^{14}t - \frac{10^7}{3}z\right)\right]\text{Wbm}^{-2}$
(c) The wave is polarized in the xy-plane with polarization angle 30° with respect to the x-axis.
(d) The refractive index of the medium is 2.

38. The magnetic field of a plane electromagnetic wave is given by: 26 July, 2022 (Shift-I)]
$\vec{B} = 2\times10^{-8}\sin(0.5\times10^3 x + 1.5\times10^{11}t)\hat{j}T$
The amplitude of the electric field would be:
(a) 6Vm^{-1} along x-axis (b) 3Vm^{-1} along z-axis
(c) 6Vm^{-1} along z-axis (d) 2×10^{-8} Vm^{-1} along z-axis

39. The oscillating magnetic field in a plane electromagnetic wave is given by $B_y = 5\times10^{-6}\sin100\pi(5x - 4\times10^8 t)T$. The amplitude of electric field will be: [26 July, 2022 (Shift-II)]
(a) 15×10^2 Vm^{-1} (b) 5×10^{-6} Vm^{-1}
(c) 16×10^{12} Vm^{-1} (d) 4×10^2 Vm^{-1}

40. Light wave traveling in air along x-direction is given by $E_y = 540\sin\pi\times10^4(x-ct)\text{Vm}^{-1}$. Then, the peak value of magnetic field of wave will be: (Given, $c = 3\times10^8\ \text{ms}^{-1}$) [25 July, 2022 (Shift-II)]
(a) 18×10^{-7} T (b) 54×10^{-7} T
(c) 54×10^{-8} T (d) 18×10^{-8} T

41. A plane electromagnetic wave travels in a medium of relative permeability 1.61 and relative permittivity 6.44. If magnitude of magnetic intensity is 4.5×10^{-2} Am^{-1} at a point, what will be the approximate magnitude of electric field intensity at that point? (Given: Permeability of free space $\mu0 = 4\pi\times10^{-7}\text{NA}^{-2}$, speed of light in vacuum $c = 3\times10^8\ \text{ms}^{-1}$) [24 June, 2022 (Shift-I)]
(a) 16.96 Vm^{-1} (b) 2.25×10^{-2} Vm^{-1}
(c) 8.48 Vm^{-1} (d) 6.75×10^6 Vm^{-1}

42. A plane electromagnetic wave of frequency 500 MHz is travelling in vacuum along y-direction. At a particular point in space and time $\vec{B} = 8.0\times10^{-8}\hat{z}T$. The value of electric field at this point is
(Speed of light = $3\times10^8\ \text{ms}^{-1}$) $\hat{x},\hat{y},\hat{z}$ are unit vectors along x, y and z direction [16 March, 2021 (Shift-I)]
(a) $24\hat{x}$ V/m (b) $2.6\hat{x}$ V/m (c) $-24\hat{x}$ V/m (d) $-2.6\hat{y}$ V/m

@TAKE_CBSE_X_OFFICIAL_EDUNET

47. A plane electromagnetic wave of frequency 100 MHz is traveling in vacuum along the x-direction. At a particular point in space and time, $\vec{B} = 2.0 \times 10^{-8}\ \hat{k}\ T$. (where, $\hat{k}$ is unit vector along z-direction) What is $\vec{E}$ at this point? (speed of light $c = 3 \times 10^8 m/s$)
[18 March, 2021 (Shift-I)]

(a) $0.6\ \hat{j}$ V/m (b) $6.0\ \hat{j}$ V/m

(c) $0.6\ \hat{k}$ V/m (d) $6.0\ \hat{k}$ V/m

44. A light beam is described by $E\ 800 \sin\omega\left(t - \frac{x}{c}\right)$. An electron is allowed to move normal to the propagation of light beam with a speed of $3 \times 10^7\ ms^{-1}$. What is the maximum magnetic force exerted on the electron?
[26 Aug, 2021 (Shift-II)]

(a) 1.28×10^{-21} N (b) 1.28×10^{-15} N

(c) 12.8×10^{-17} N (d) 12.8×10^{-19} N

45. A plane electromagnetic wave propagating along y-direction, can have the following pair of electric field ($\vec{E}$) and magnetic field ($\vec{B}$) components:
[18 March, 2021 (Shift-II)]

(a) E_y, B_y or E_z, B_x (b) E_y, B_x or E_z, B_y

(c) E_x, B_z or E_z, B_x (d) E_x, B_y or E_y, B_x

46. A plane electromagnetic wave with frequency of 30 MHz travels in free space. At particular point in space and time, electric field is 6 V/m. The magnetic field at this point will be $x \times 10^{-8}$ T. The value of x is _____.
[27 Aug, 2021 (Shift-II)]

47. The magnetic field vector of an electromagnetic wave is given by $B = B_0 = \frac{\hat{i}+\hat{j}}{\sqrt{2}}\cos(kz - \omega t)$ where $\hat{i}, \hat{j}$ represents unit vector along x and y-axis respectively. At $t = 0$ s, two electric charges q_1 of 4π coulomb and q_2 of 2π coulomb located at $\left(0,0,\frac{\pi}{k}\right)$ and $\left(0,0,\frac{3\pi}{k}\right)$ respectively, have the same velocity of 0.5 c $\hat{i}$ (where c is the velocity of light). The ratio of the force acting on charge q_1 to q_2 is:
[31 Aug, 2021 (Shift-II)]

(a) $2\sqrt{2}:1$ (b) $1:\sqrt{2}$ (c) $2:1$ (d) $\sqrt{2}:1$

48. The electric field of a plane electromagnetic wave propagating along the x direction in vaccum is $\vec{E} = E_0 \cos(\omega t - kx)\hat{j}$. The magnetic field $\vec{B}$, at the moment $t = 0$ is
[3 Sep, 2020 (Shift-II)]

(a) $\vec{B} = E_0\sqrt{\mu_0\varepsilon_0}\cos(kx)\hat{j}$ (b) $\vec{B} = E_0\sqrt{\mu_0\varepsilon_0}\cos(kx)\hat{k}$

(c) $\vec{B} = \frac{E_0}{\sqrt{\mu_0\varepsilon_0}}\cos(kx)\hat{k}$ (d) $\vec{B} = \frac{E_0}{\sqrt{\mu_0\varepsilon_0}}\cos(kx)\hat{j}$

49. For a plane electromagnetic wave, the magnetic field at a point x and time t is
[6 Sep, 2020 (Shift-II)]

$\vec{B}(x,t) = [1.2\times10^{-7}\sin(0.5\times10^3 x + 1.5\times10^{11} t)\hat{k}]T.$

The instantaneous electric field $\vec{E}$ corresponding to $\vec{B}$ is (speed of light $c = 3 \times 10^8\ ms^{-1}$)

(a) $\vec{E}(x,t) = [36\sin(1\times10^3 x + 1.5\times10^{11} t)\hat{i}]\frac{V}{m}$

(b) $\vec{E}(x,t) = [36\sin(0.5\times10^3 x + 1.5\times10^{11} t)\hat{k}]\frac{V}{m}$

(c) $\vec{E}(x,t) = [-36\sin(0.5\times10^3 x + 1.5\times10^{11} t)\hat{j}]\frac{V}{m}$

(d) $\vec{E}(x,t) = [36\sin(1\times10^3 x + 1.5\times10^{11} t)\hat{j}]\frac{V}{m}$

50. A plane electromagnetic wave of frequency 25 GHz is propagating in vacuum along the z-direction. At a particular point in space and time, the magnetic field is given by $\vec{B} = 5\times10^{-8}\ \hat{j}\ T$. The corresponding electric field $\vec{E}$ is
(Speed of light $c = 3 \times 10^8 ms^{-1}$) [8 Jan, 2020 (Shift-II)]

(a) $-1.66\times10^{-14}\ \hat{i}$ V/m (b) $-15\hat{i}$ V/m

(c) $15\hat{i}$ V/m (d) $1.66\times10^{-14}\ \hat{i}$ V/m

51. The magnetic field of a plane electromagnetic wave is
$\vec{B} = 3 \times 10^{-8}\sin[200\pi(y + ct)]\hat{i}T$
Where $c = 3 \times 10^8\ ms^{-1}$ is the speed of light.
The corresponding electric field is [03 Sep, 2020 (Shift-I)]

(a) $\vec{E} = 9\sin[200\pi(y + ct)]\hat{k}V/m$

(b) $\vec{E} = -9\sin[200\pi(y + ct)]\hat{k}V/m$

(c) $\vec{E} = 3\times10^{-8}\sin[200\pi(y + ct)]\hat{k}V/m$

(d) $\vec{E} = -10^{-6}\sin[200\pi(y + ct)]\hat{k}V/m$

52. An electron is constrained to move along the y - axis with a speed of 0.1c (c is the speed of light) in the presence of electromagnetic wave, whose electric field is $\vec{E} = 30\hat{j}\sin(1.5\times10^7 t - 5\times10^{-2} x)V/m$.
The maximum magnetic force experienced by the electron will be:
(given $c = 3 \times 10^8\ ms^{-1}$ and electron charge $= 1.6 \times 10^{-19}$ C)
[5 Sep, 2020 (Shift-I)]

(a) 3.2×10^{-18} N (b) 1.5×10^{-19} N

(c) 2.4×10^{-18} N (d) 4.8×10^{-19} N

53. The electric field of a plane electromagnetic wave is given by $\vec{E} = E_0(\hat{x} + \hat{y})\sin(kz - \omega t)$. Its magnetic field will be given by
[04 Sep, 2020 (Shift-II)]

(a) $\frac{E_0}{c}(\hat{x} - \hat{y})\cos(kz - \omega t)$ (b) $\frac{E_0}{c}(\hat{x} - \hat{y})\sin(kz - \omega t)$

(c) $\frac{E_0}{c}(-\hat{x} + \hat{y})\sin(kz - \omega t)$ (d) $\frac{E_0}{c}(\hat{x} - \hat{y})\sin(kz - \omega t)$

54. If the magnetic field in a plane electromagnetic wave is given by $\vec{B} = 3 \times 10^{-8}\sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\ \hat{j}\ T$, then what will be expression for electric field?
[7 Jan, 2020 (Shift-I)]

(a) $\vec{E} = (3 \times 10^{-8}\sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\ \hat{j}$ V/m)

(b) $\vec{E} = (3 \times 10^{-8}\sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\ \hat{i}$ V/m)

(c) $\vec{E} = (60\sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\ \hat{k}$ V/m)

(d) $\vec{E} = (9\sin(1.6 \times 10^3 x + 48 \times 10^{10} t)\ \hat{k}$ V/m)

55. In a plane electromagnetic wave, the directions of electric field and magnetic field are represented by $\hat{k}$ and $2\hat{i} - 2\hat{j}$ respectively. What is the unit vector along the direction of propagation of the wave?
[2 Sep, 2020 (Shift-II)]

(a) $\frac{1}{\sqrt{5}}(\hat{i} + 2\hat{j})$ (b) $\frac{1}{\sqrt{2}}(\hat{i} + \hat{k})$

(c) $\frac{1}{\sqrt{2}}(\hat{i} + \hat{j})$ (d) $\frac{1}{\sqrt{5}}(2\hat{i} + \hat{j})$

@RAKESH_BSNL_JE_RAJ_BSNL

56. The electric fields of two plane electromagnetic plane waves in vacuum are given by $\vec{E}_1 = E_0\hat{j}\cos(\omega t - kx)$ and $\vec{E}_2 = E_0\hat{k}\cos(\omega t - ky)$. At $t = 0$, a particle of charge q is at origin with a velocity $\vec{v} = (0.8c)\hat{j}$ (c is the speed of the light in vacuum). The instantaneous force experienced by the particle is **[9 Jan, 2020 (Shift-I)]**

(a) $E_0q(0.8\hat{i}+\hat{j}+0.2\hat{k})$ (b) $E_0q(-0.8\hat{i}+\hat{j}+\hat{k})$

(c) $E_0q(0.4\hat{i}-3\hat{j}+0.8\hat{k})$ (d) $E_0q(0.8\hat{i}-\hat{j}+0.4\hat{k})$

57. The electric field of a plane electromagnetic wave is given by $\vec{E} = E_0\hat{i}\cos(kz)\cos(\omega t)$. The corresponding magnetic field $\vec{B}$ is then given by **[10 April, 2019 (Shift-I)]**

(a) $\vec{B} = \frac{E_0}{c}\hat{j}\sin(kz)\cos(\omega t)$ (b) $\vec{B} = \frac{E_0}{c}\hat{j}\sin(kz)\sin(\omega t)$

(c) $\vec{B} = \frac{E_0}{c}\hat{k}\sin(kz)\cos(\omega t)$ (d) $\vec{B} = \frac{E_0}{c}\hat{j}\cos(kz)\sin(\omega t)$

58. A plane electromagnetic wave of frequency 50 MHz travels in free space along the positive x-direction. At a particular point in space and time, $\vec{E} = 6.3\hat{j}$ V/m. The corresponding $\vec{B}$, at that point will be **[9 Jan, 2019 (Shift-I)]**

(a) $18.9 \times 10^{-8}\,\hat{k}$T (b) $2.1 \times 10^{-8}\,\hat{k}$T

(c) $6.3 \times 10^{-8}\,\hat{k}$T (d) $18.9 \times 10^{8}\,\hat{k}$T

59. The magnetic field of an electromagnetic wave is given by

$$\vec{B} = 1.6\times10^{-6}\cos\left(2\times10^{7}z + 6\times10^{15}t\right)\left(2\hat{i}+\hat{j}\right)\frac{Wb}{m^2}$$

The associated electric field will be **[8 April, 2019 (Shift-II)]**

(a) $\vec{E} = 4.8\times10^{2}\cos\left(2\times10^{7}z + 6\times10^{15}t\right)\left(\hat{i}-2\hat{j}\right)\frac{V}{m}$

(b) $\vec{E} = 4.8\times10^{2}\cos\left(2\times10^{7}z - 6\times10^{15}t\right)\left(2\hat{i}+\hat{j}\right)\frac{V}{m}$

(c) $\vec{E} = 4.8\times10^{2}\cos\left(2\times10^{7}z - 6\times10^{15}t\right)\left(-2\hat{j}+\hat{i}\right)\frac{V}{m}$

(d) $\vec{E} = 4.8\times10^{2}\cos\left(2\times10^{7}z + 6\times10^{15}t\right)\left(-\hat{i}+2\hat{j}\right)\frac{V}{m}$

60. A plane electromagnetic wave travels in free space along the x-direction. The electric field component of the wave at a particular point of space and time is $E = 6\text{Vm}^{-1}$ along y-direction. Its corresponding magnetic field component, B would be **[8 April, 2019 (Shift-I)]**

(a) 6×10^{-8} T along z-direction (b) 6×10^{-8} T along x-direction

(c) 2×10^{-8} T along z-direction (d) 2×10^{-8} T along y-direction

61. The magnetic field of a plane electromagnetic wave is given by $\vec{B} = B_0\hat{i}\left[\cos\left(kz-\omega t\right)\right] + B_1\hat{j}\cos\left(kz+\omega t\right)$ where $B_0 = 3 \times 10^{-5}$ T and $B_1 = 2 \times 10^{-6}$ T. The rms value of the force experienced by a stationary charge $Q = 10^{-4}$ C at $z = 0$ is closest to **[9 April, 2019 (Shift-I)]**

(a) 0.9 N (b) 0.1 N (c) 3×10^{-2}N (d) 0.6 N

62. The electric field of a plane polarized electromagnetic wave in free space at time $t = 0$ is given by an expression

$\vec{E}(x,y) = 10\hat{j}\cos[6x+8z]$

The magnetic field $B(x, z, t)$ is given by (c is the velocity of light) **[10 Jan, 2019 (Shift-II)]**

(a) $\frac{1}{c}\left(6\hat{k}+8\hat{i}\right)\cos[(6x - 8z + 10ct)]$

(b) $\frac{1}{c}\left(6\hat{k}-8\hat{i}\right)\cos[(6x + 8z - 10ct]$

(c) $\frac{1}{c}\left(6\hat{k}+8\hat{i}\right)\cos[(6x + 8z - 10ct)]$

(d) $\frac{1}{c}\left(6\hat{k}-8\hat{i}\right)\cos[(6x + 8z + 10ct)]$

63. An electromagnetic wave of intensity 50 Wm^{-2} enters in a medium of refractive index 'n' without any loss. The ratio of the magnitudes of electric fields, and the ratio of the magnitudes of magnetic fields of the wave before and after entering into the medium are respectively, given by **[11 Jan, 2019 (Shift-I)]**

(a) $\left(\frac{1}{\sqrt{n}}, \frac{1}{\sqrt{n}}\right)$ (b) $\left(\sqrt{n}, \sqrt{n}\right)$

(c) $\left(\sqrt{n}, \frac{1}{\sqrt{n}}\right)$ (d) $\left(\frac{1}{\sqrt{n}}, \sqrt{n}\right)$

64. If the magnetic field of a plane electromagnetic wave is given by (The speed of light = 3×10^8 m/s)

$B = 1001 \times 10^{-4}\sin\left[2\pi\times2\times10^{15}\left(t-\frac{x}{c}\right)\right]$ then the maximum electric field associated with it is **[10 Jan, 2019 (Shift-I)]**

(a) 6×10^4 N/C (b) 3×10^4 N/C

(c) 4×10^4 N/C (d) 4.5×10^4 N/C

Momentum, Radiation Pressure, Energy Density and Intensity of EM Wave

65. Electromagnetic waves travel in a medium with speed of 1.5×10^8 ms^{-1}. The relative permeability of the medium is 2.0. The relative permittivity will be: **[06 April, 2024 (Shift-I)]**

(a) 5 (b) 1 (c) 4 (d) 2

66. Average force exerted on a non-reflecting surface at normal incidence is 2.4×10^{-4}N. If 360 W/cm^2 is the light energy flux during span of 1 hour 30 minutes. Then the area of the surface is: **[08 April, 2024 (Shift-I)]**

(a) 0.2 m^2 (b) 0.02 m^2 (c) 20 m^2 (d) 0.1 m^2

67. In a plane EM wave, the electric field oscillates sinusoidally at a frequency of 5×10^{10} Hz and an amplitude of 50 Vm^{-1}. The total average energy density of the electromagnetic field of the wave is: **[31 Jan, 2024 (Shift-I)]**

[Use $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/Nm^2]

(a) 1.106×10^{-8} Jm^{-3} (b) 4.425×10^{-8} Jm^{-3}

(c) 2.212×10^{-8} Jm^{-3} (d) 2.212×10^{-10} Jm^{-3}

68. Given below are two statements: **[31 Jan, 2024 (Shift-II)]**

Statement-I: Electromagnetic waves carry energy as they travel through space and this energy is equally shared by the electric and magnetic fields. **[31 Jan, 2024 (Shift-II)]**

Statement-II: When electromagnetic waves strike a surface, a pressure is exerted on the surface. In the light of the above statements, choose the most appropriate answer from the options given below: **[31 Jan, 2024 (Shift-II)]**

(a) Statement-I is incorrect but Statement-II is correct

(b) Both Statement-I and Statement-II are correct

(c) Both Statement-I and Statement-II are incorrect.

(d) Statement-I is correct but Statement-II is incorrect.

@FAST_CBSE_X_@RAJ_EDUNET

70. A point source of light is placed at the centre of curvature of a hemispherical surface. The source emits a power of 24 W The radius of curvature of hemisphere is 10 cm and the inner surface is completely reflecting. The force on the hemisphere due to the light falling on it is _____ × 10⁻⁸ N. [30 Jan 2023 (Shift-I)]

71. For the plane electromagnetic wave given by $E = E_0 \sin(\omega t - kx)$ and $B = B_0 \sin(\omega t - kx)$, the ratio of average electric energy density to average magnetic energy density is

(a) 1 (b) 1/2 (c) 2 (d) 4 [06 April, 2023 (Shift-I)]

72. The electric field in an electromagnetic wave is given as

$\vec{E} = 20\sin\omega\left(t - \frac{x}{c}\right)\hat{j} NC^{-1}$

Where ω and C are angular frequency and velocity of electromagnetic wave respectively. The energy contained in a volume of 5×10^{-4} m³ will be

(Given $\varepsilon_0 = 8.85 \times 10^{-12}$ C² / Nm²) [11 April, 2023 (Shift-I)]

(a) 28.5×10^{-13} J (b) 17.7×10^{-13} J

(c) 8.85×10^{-13} J (d) 88.5×10^{-13} J

73. The energy of an electromagnetic wave contained in a small volume oscillates with [10 April, 2023 (Shift-I)]

(a) Zero frequency

(b) Half the frequency of the wave

(c) Double the frequency of the wave

(d) The frequency of the wave

74. The ratio of average electric energy density and total average energy density of electromagnetic wave is: [01 Feb, 2023 (Shift-II)]

(a) 2 (b) 1 (c) 3 (d) $\frac{1}{2}$

75. A point source of 100 W emits light with 5% efficiency. At a distance of 5m from the source, the intensity produced by the electric field component is: [30 Jan 2023 (Shift-II)]

(a) $\frac{1}{2\pi}\frac{W}{m^2}$ (b) $\frac{1}{40\pi}\frac{W}{m^2}$ (c) $\frac{1}{10\pi}\frac{W}{m^2}$ (d) $\frac{1}{20\pi}\frac{W}{m^2}$

76. The electric field in an electromagnetic wave is given by $E = 56.5\sin\omega(t - x/c) NC^{-1}$. Find the intensity of the wave if it is propagating along x-axis in the free space.

(Given: $\varepsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$) [25 June, 2022 (Shift-I)]

(a) 5.65 Wm⁻² (b) 4.24 Wm⁻²

(c) 1.9×10^{-7} Wm⁻² (d) 56.5 Wm⁻²

77. Sun light falls normally on a surface of area 36cm² and exerts an average force of 7.2×10^{-9}N within a time period of 20 minutes. Considering a case of complete absorption, the energy flux of incident light is [28 July, 2022 (Shift-II)]

(a) 25.92×10^2 W/cm² (b) 8.64×10^{-6}W/cm²

(c) 6.0W/cm² (d) 0.06W/cm²

78. The intensity of the light from a bulb incident on a surface is 0.22 W/m². The amplitude of the magnetic field in this light-wave is _____ × 10⁻⁹ T.

(Given: Permittivity of vacuum $\varepsilon_0 = 8.85 \times 10^{-12}$ C²N⁻¹m⁻², speed of light in vacuum $c = 3 \times 10^8$ ms⁻¹) [29 June, 2022 (Shift-I)]

79. For an electromagnetic wave travelling in free space, the relation between average energy densities due to electric (U_e) and magnetic (U_m) field is [16 March, 2021 (Shift-I)]

(a) $U_e > U_m$ (b) $U_e = U_m$ (c) $U_e \neq U_m$ (d) $U_e < U_m$

80. If 2.5×10^{-4} N average force is exerted by a light wave on a non-reflecting surface of 30 cm² area during 40 minutes of time span, the energy flux of light just before it falls on the surface is _____ W / cm². (Round off to the Nearest Integer)

(Assume complete absorption and normal incidence conditions are there) [17 March, 2021 (Shift-I)]

81. The electric field intensity produced by the radiation coming from a 100 W bulb at a distance of 3m is E. The electric field intensity produced by the radiation coming from 60 W at the same distance is $\sqrt{\frac{x}{5}}E$. The value of x = _____. [17 March, 2021 (Shift-II)]

82. A radiation is emitted by 1000 W bulb and it generates an electric field and magnetic field at P, placed at a distance of 2 m. The efficiency of the bulb is 1.25%. The value of peak electric field at P is $x \times 10^{-1}$ V/m. Value of x is _____. (Rounded - off to the nearest integer)

[Take $\varepsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$, $c = 3 \times 10^8$ ms⁻¹] [26 Feb, 2021 (Shift-I)]

83. The electric field in an electromagnetic wave is given by $E = (50$ NC⁻¹$) \sin\omega(t - x/c)$. The energy contained in a cylinder of volume V is 5.5×10^{-12} J. The value of V is _____cm³.

(given by $\varepsilon_0 = 8.8 \times 10^{-12}$ C²N⁻¹m⁻²) [31 Aug, 2021 (Shift-I)]

84. The peak electric field produced by the radiation coming from the 8 W bulb at a distance of 10 m is $\frac{x}{10}\sqrt{\frac{\mu_0 c}{\pi}\frac{V}{m}}$. The efficiency of the bulb is 10% and it is a point source. The value of x is.....

[25 Feb, 2021 (Shift-II)]

85. Intensity of sunlight is observed as 0.092 Wm^{-2} at a point in free space. What will be the peak value of magnetic field at that point? ($\varepsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$) [22 July, 2021 (Shift-II)]

(a) 5.88 T (b) 1.96×10^{-8} T

(c) 8.31 T (d) 2.77×10^{-8} T

86. A plane electromagnetic wave, has frequency of 2.0×10^{10} Hz and its energy density is 1.02×10^{-8} J/m³ in vacuum. The amplitude of the magnetic field of the wave is close to

($\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \frac{Nm^2}{C^2}$ and speed of light = 3×10^8 ms⁻¹) [2 Sep, 2020 (Shift-I)]

(a) 110 nT (b) 140 nT (c) 190 nT (d) 160 nT

87. Suppose that intensity of a laser is $\left(\frac{315}{\pi}\right) W/m^2$. The rms electric field, in units of V/m associated with this source is close to the nearest integer is $\left(\varepsilon_0 = 8.86 \times 10^{-12} C^2 Nm^{-2}; c = 3 \times 10^8 ms^{-1}\right)$ [6 Sep, 2020 (Shift-I)]

88. The dimension of $\frac{B^2}{2\mu_0}$, where B is magnetic field and μ_0 is the magnetic permeability of vacuum, is [7 Jan, 2020 (Shift-II)]

(a) ML^2T^{-1} (b) $ML^{-1}T^{-2}$ (c) ML^2T^{-1} (d) MLT^{-2}

@FIITJEE_OFFICIAL

88. The energy associated with electric field is (U_E) and with magnetic field is (U_B) for an electromagnetic wave in free space.
[9 Jan, 2019 (Shift-II)]
(a) $U_E = \frac{U_B}{2}$ (b) $U_E > U_B$ (c) $U_E < U_B$ (d) $U_E = U_B$

89. A 27 mW laser beam has a cross-sectional area of 10 mm². The magnitude of the maximum electric field in this electromagnetic wave is given by
[Given: Permittivity of space $\varepsilon_0 = 9 \times 10^{-12}$ F/m units, speed of light $= c = 3 \times 10^8$ m/s] [11 Jan, 2019 (Shift-II)]
(a) 2 kV/m (b) 0.7 kV/m (c) 1 kV/m (d) 1.4 kV/m

90. The mean intensity of radiation on the surface of the Sun is about 10^8 W/m². The rms value of the corresponding magnetic field is closet to : [12 Jan, 2019 (Shift-II)]
(a) 1 T (b) 10^2 T (c) 10^{-2} T (d) 10^{-4} T

Types of EM Waves

91. Arrange the following in the ascending order of wavelength:
[04 April, 2024 (Shift-II)]
(a) $\lambda_1 > \lambda_2 > \lambda_3 > \lambda_4$ (b) $\lambda_2 > \lambda_3 > \lambda_4 > \lambda_1$
(c) $\lambda_1 < \lambda_2 < \lambda_3 < \lambda_4$ (d) $\lambda_3 > \lambda_2 > \lambda_1 > \lambda_4$

92. Match List-I with List-II:

List-I EM-Wave		List-II Wavelength Range	
(A)	Infra-red	(I)	$< 10^{-3}$ nm
(B)	Ultraviolet	(II)	400 nm to 1 nm
(C)	X-rays	(III)	1 mm to 700 nm
(D)	Gamma rays	(IV)	1 nm to 10^{-3} nm

Choose the correct answer from the options given below:
[05 April, 2024 (Shift-II)]
(a) (A)-(II), (B)-(I), (C)-(IV), (D)-(III)
(b) (A)-(III), (B)-(II), (C)-(IV), (D)-(I)
(c) (A)-(IV), (B)-(III), (C)-(II), (D)-(I)
(d) (A)-(I), (B)-(III), (C)-(II), (D)-(IV)

93. Match List-I with List-II of Electromagnetic waves with corresponding wavelength range:

List-I		List-II	
(A)	Microwave	(I)	400 nm to 1 nm
(B)	Ultraviolet	(II)	1 nm to 10^{-3} nm
(C)	X-Ray	(III)	1 mm to 700 nm
(D)	Infra-red	(IV)	0.1 m to 1 mm

Choose the correct answer from the options given below :
[15 April, 2023 (Shift-1)]
(a) (A)-(I), (B)-(IV), (C)-(II), (D)-(III)
(b) (A)-(IV), (B)-(I), (C)-(II), (D)-(III)
(c) (A)-(IV), (B)-(II), (C)-(I), (D)-(III)
(d) (A)-(IV), (B)-(I), (C)-(III), (D)-(II)

94. Match the List-I with List-II: [01 Feb 2023 (Shift-I)]

List-I		List-II	
A.	Microwaves	I.	Radio active decay of the nucleus
B.	Gamma rays	II.	Rapid acceleration and deceleration of electron in aerials
C.	Radio waves	III.	Inner shell electrons
D.	X-rays	IV.	Klystron valve

Choose the correct answer from the options given below:
(a) A → I, B → II, C → III, D → IV
(b) A → IV, B → I, C → II, D → III
(c) A → I, B → III, C → IV, D → II
(d) A → IV, B → III, C → II, D → I

95. Match List-I with List-II. [31 Jan 2023 (Shift-II)]

List-I		List-II	
A	Microwaves	I	Physiotherapy
B	UV rays	II	Treatment ofcancer
C	Infra-red rays	III	Lasik eye surgery
D	X-rays	IV	Aircraft navigation

Choose the correct answer from the option given below:
(a) A → II, B → IV, C → III, D → I
(b) A → IV, B → I, C → II, D → III
(c) A → IV, B → III, C → I, D → II
(d) A → III, B → II, C → I, D → IV

96. Match Column-I and Column-II

Column-I		Column-II	
A.	Ultraviolet rays	p.	Study crystal
B.	Microwaves	q.	Greenhouse effect
C.	Infrared waves	r.	Sterilizing surgical instrument
D.	X-rays	s.	Radar system

Choose the correct answer from the option given below
[27 June, 2022 (Shift-I)]
(a) A-(r); B-(s); C-(q); D-(p) (b) A-(q); B-(p); C-(s); D-(r)
(c) A-(r); B-(q); C-(p); D-(s) (d) A-(q); B-(p); C-(r); D-(s)

97. Which is the correct ascending order of wavelength?
[26 June, 2022 (Shift-II)]
(a) $\lambda_{visible} < \lambda_{X\text{-ray}} < \lambda_{gamma\text{-ray}} < \lambda_{microwave}$
(b) $\lambda_{gamma\text{-ray}} < \lambda_{X\text{-ray}} < \lambda_{visible} < \lambda_{microwave}$
(c) $\lambda_{X\text{-ray}} < \lambda_{gamma\text{-ray}} < \lambda_{visible} < \lambda_{microwave}$
(d) $\lambda_{microwave} < \lambda_{visible} < \lambda_{gamma\ ray} < \lambda_{X\text{-ray}}$

98. Match List - I with List - II:

List-I		List-II	
(A)	UV rays	(i)	Diagnostic tool in medicine
(B)	X-rays	(ii)	Water purification
(C)	Microwave	(iii)	Communication, Radar
(D)	Infrared wave	(iv)	Improving visibility in foggy days

Choose the correct answer from the options given below:
[29 July, 2022 (Shift-I)]
(a) (A) - (iii), (B) - (ii), (C) - (i), (D)- (iv)
(c) (A) - (ii), (B) - (iv), (C) - (iii), (D) - (i)
(b) (A) - (ii), (B) - (i), (C) - (iii), (D) - (iv)
(d) (A) - (iii), (B) - (i), (C) - (ii), (D) - (iv)

PEAK CBSE X IS HEREDUNET

99. Match column-I with column-II

	Column-I		Column-II
A.	Television signal	p.	03 KHz
B.	Radio signal	q.	20 KHz
C.	High quality music	r.	02 MHz
D.	Human speech	s.	06 MHz

Choose the correct answer from the following options given below [28 June, 2022 (Shift-I)]

(a) A-(p); B-(q); C-(r); D-(s)
(b) A-(s); B-(r); C-(p); D-(q)
(c) A-(s); B-(r); C-(q); D-(p)
(d) A-(p); B-(q); C-(s); D-(r)

100. The correct match between the entries in column I and column II are: [5 Sep, 2020 (Shift-II)]

	Radiation-I		Wavelength-II
A.	Microwave	(i)	100 m
B.	Gamma rays	(ii)	10^{-13} m
C.	A.M. radio waves	(iii)	10^{-10} m
D.	X-rays	(iv)	10^{-3} m

(a) (a)-(iv), (b)-(ii), (c)-(i), (d)-(iii)
(c) (a)-(iii), (b)-(ii), (c)-(i), (d)-(iv)
(b) (a)-(i), (b)-(iii), (c)-(iv), (d)-(ii)
(d) (a)-(ii), (b)-(i), (c)-(iv), (d)-(iii)

101. Choose the correct option relating wavelengths of different parts of electromagnetic wave spectrum [04 Sep, 2020 (Shift-I)]

(a) $\lambda_{x\text{-rays}} < \lambda_{\text{gamma rays}} < \lambda_{\text{radio waves}} < \lambda_{\text{visible}}$
(b) $\lambda_{\text{visible}} > \lambda_{x\text{-rays}} > \lambda_{\text{radio waves}} > \lambda_{\text{gamma rays}}$
(c) $\lambda_{\text{radio waves}} > \lambda_{\text{gamma rays}} > \lambda_{\text{visible}} > \lambda_{x\text{-rays}}$
(d) $\lambda_{\text{visible}} < \lambda_{\text{gamma rays}} < \lambda_{\text{radio waves}} < \lambda_{x\text{-rays}}$

JEE-Advanced

EM Wave

Multiple Correct

1. The electric field associated with an electromagnetic wave propagating in a dielectric medium is given by $\vec{E} = 30(2\hat{x} + \hat{y}) \sin\left[2\pi\left(5\times10^{14}t - \frac{10^7}{3}Z\right)\right]$ V m^{-1}. Which of the following option(s) is/ are correct? C-5.82 W-36.39 UA-40.7 PC-17 09 (JEE Adv. 2023)

[Given: The speed of light in vacuum, $c = 3 \times 10^8$ m s^{-1}]

(a) $B_z = -2 \times 10^{-7} \sin\left[2\pi\left(5\times10^{14}t - \frac{10^7}{3}Z\right)\right]$ Wb m^{-2}.

(b) $B_z = 2 \times 10^{-7} \sin\left[2\pi\left(5\times10^{14}t - \frac{10^7}{3}Z\right)\right]$ Wb m^{-2}.

(c) The wave is polarized in the xy-plane with polarization angle 30° with respect to the x-axis.

(d) The refractive index of the medium is 2.

ANSWER KEY

JEE-Main

1. (d)	2. (a)	3. (a)	4. [8]	5. (b)	6. (b)	7. (c)	8. (c)	9. (d)	10. (d)
11. [6]	12. (c)	13. (c)	14. (c)	15. [667]	16. [15]	17. (c)	18. (d)	19. (c)	20. (c)
21. (c)	22. (c)	23. (a)	24. (d)	25. (d)	26. (a)	27. (b)	28. (b)	29. (b)	30. (a)
31. (b)	32. (c)	33. (b)	34. (b)	35. (a)	36. (a)	37. (a,d)	38. (c)	39. (d)	40. (a)
41. (c)	42. (c)	43. (b)	44. (d)	45. (c)	46. [2]	47. (c)	48. (b)	49. (c)	50. (c)
51. (b)	52. (d)	53. (c)	54. (d)	55. (c)	56. (a)	57. (b)	58. (b)	59. (d)	60. (c)
61. (d)	62. (d)	63. (c)	64. (b)	65. (d)	66. (b)	67. (a)	68. (b)	69. [4]	70. (a)
71. (c)	72. (c)	73. (d)	74. (b)	75. (b)	76. (d)	77. [43]	78. (b)	79. [25]	80. [3]
81. [137]	82. [500]	83. [2]	84. (d)	85. (d)	86. [194]	87. (b)	88. (d)	89. (d)	90. (d)
91. (c)	92. (b)	93. (b)	94. (b)	95. (c)	96. (a)	97. (b)	98. (b)	99. (c)	100. (a)
101. (c)									

JEE-Advanced

1. (a, d)

@FAKE_CBSE_X@RAJEDUNET

EXPLANATIONS

JEE-Main

1. (*d*) Displacement current is same as conduction current in capacitor. Hence,

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

$$= \frac{1}{2\pi \times 4\times10^{3}\times12\times10^{-6}} = 3.317\ \Omega$$

$$I = \frac{V}{X_C} = \frac{40}{3.317} = 12A$$

2. (*a*) Direction of magnetic field vector will be in the direction of $\hat{K}\times\hat{E}$

magnitude of magnetic field $B = \frac{E}{C} = \frac{K}{\omega}E$

$$\Rightarrow \vec{B} = \frac{1}{\omega}\left(\vec{K}\times\vec{E}\right)$$

3. (*a*) As, poynting vector is given by

$\vec{S} = \vec{E}\times\vec{H}$

Given, energy transport is in the negative z direction and Electric field is in the positive y direction

$$\Rightarrow\left(-\hat{k}\right) = \left(+\hat{j}\right)\times\left[\hat{i}\right]$$

Hence according to cross product of vectors magnetic field should be in the positive x direction.

4. [8] Displacement current,

$$I_d = C_d\frac{dv}{dt} = \frac{\varepsilon_0 A}{d}\frac{dv}{dt}$$

$$= \frac{8.85\times10^{-12}\times40\times10^{-4}}{x\times10^{-3}}$$

$$\Rightarrow 4.425\times10^{-6} = \frac{8.85\times10^{-12}\times40\times10^{-4}}{x\times10^{-3}}$$

$$\Rightarrow x = 8$$

5. (*b*) Second and fourth statements are correct.

6. (*b*) $\hat{E}\times\hat{B}$ must be direction of propagation.

7. (*c*) The statement II is wrong as the velocity of wave in a medium is $\frac{1}{\sqrt{\mu_r\mu_0\varepsilon_r\varepsilon_0}}$

8. (*c*) $\vec{H} = \frac{\vec{B}}{\mu_0} \Rightarrow \vec{B} = \frac{1}{c}\left(\vec{k}\times\vec{E}\right)$

9. (*d*) Given: $E = 20\cos(2\times10^{10}t - 200x)$ V/m

$\Rightarrow \omega = 2\times10^{10}, K = 200$

$$\text{Wave speed} = \frac{2\times10^{10}}{200} = 10^{8}\ \text{m/s}$$

$$\text{Refractive Index} = \frac{C}{\text{speed}} = \frac{3\times10^{8}}{10^{8}} = 3$$

$$3 = \sqrt{\varepsilon_r\times1}$$

[$\because$ As refractive index $= \sqrt{\mu_r\varepsilon_r}$]

$\varepsilon_r = 9$

10. (*d*) $I_d = C_d\frac{dV}{dt} = \frac{\varepsilon_0 A}{d}\frac{d}{dt}(20\sin\omega t)$

$$= \frac{\varepsilon_0 A}{d}\times20\omega\cos\omega t$$

$\therefore$ Amplitude of oscillating displacement current

$$= \frac{\varepsilon_0 A}{d}\times20\omega = \frac{8.85\times10^{-12}\times1\times20\times100\pi}{2\times10^{-3}}$$

$$= 27.79\ \mu A$$

11. [6] $J_C = \frac{E}{r} = \frac{V}{r\,d} = \frac{V_0\sin(2pft)}{r\,d}$

$$J_d = \frac{\in}{d}\frac{dV}{dt} = \frac{2\pi f\in}{d}V_0\cos(2\pi ft)$$

$$\frac{J_c}{J_d} = \frac{\tan(2\pi ft)}{2\pi f\in\rho} = \frac{\tan\left(2\pi\times\frac{900}{800}\right)}{2\pi\times9\times10^{2}\times80\in_0\times0.25}$$

$$= 10^{6}$$

12. (*c*) Reflected wave will be $3.1\cos[1.8z + (5.4\times10^{6})t]\hat{i}$ N/C, comparing it with $E_0\cos(Kz+\omega t)\hat{i}\frac{N}{C}$

$K = 1.8$

$$\frac{2\pi}{\lambda} = 1.8$$

$$\lambda = \frac{2\pi}{1.8} = \frac{\pi}{0.9} = \frac{10\pi}{9} = 3.48\text{m}$$

13. (*c*) We have given, $\vec{E} = E_0\hat{i}, \vec{B} = B_0\hat{k}$

Direction of propagation $(\hat{p})$ of wave is given as, $\hat{p} = \hat{E}\times\hat{B} = \hat{i}\times\hat{k} = (-\hat{j})$

14. (*c*) On comparing with equation, $E = E_0\sin(kx - \omega t)$, we get

$\omega = 10\times10^{10}$ rad/s

$k = 500$

$$\therefore \text{Velocity, } v = \frac{\text{coefficient of time}}{\text{coefficiont of } x} = \frac{\omega}{k}$$

$$\Rightarrow v = \frac{10\times10^{10}}{500} = 2\times10^{8} = \frac{2\times c}{3}$$

15. [667] $f = 3\ \text{GHz} = 3\times10^{9}\ \text{Hz}$

$$\lambda_{\text{vacuum}} = \frac{v}{f} = \frac{3\times10^{8}\ \text{m/s}}{3\times10^{9}\ \text{m/s}} = 10^{-1}\ \text{m} = 0.1\ \text{m}$$

$$\lambda_{\text{vacuum}} = \frac{\lambda_{\text{vacuum}}}{\mu_{\text{medium}}} = \frac{0.1}{\mu_{\text{medium}}}$$

$$\mu_{\text{medium}} = \sqrt{\mu_r\in_r} = \sqrt{1\times2.25} = 1.5$$

$$\therefore \mu_{\text{medium}} = \frac{0.1\ \text{m}}{1.5} = 0.0667\ \text{m}$$

$$= 6.67\ \text{cm} = 667\times10^{-2}\ \text{cm}$$

16. [15] We know that, velocity of electro magnetic wave in any medium, $v = \frac{1}{\sqrt{\varepsilon\mu}}$

According to the question, $\varepsilon_r = 2, \mu_r = 2$

$$\therefore v = \frac{1}{\sqrt{\varepsilon_0\in_r\mu_0\mu_r}} = \frac{1}{\sqrt{2\varepsilon_0\times2\mu_0}}$$

$$= \frac{1}{2\sqrt{\varepsilon_0\mu_0}}$$

$$= 15\times10^{7}\ \text{m/s}.$$

17. (*c*) EM wave is in direction $\rightarrow \frac{\hat{i}+\hat{j}}{\sqrt{2}}$

Electric field is in direction $\rightarrow \hat{k}$

$\vec{E}\times\vec{B}\rightarrow$ direction of propagation of EM wave

18. (*d*) Electric field at $t = 0$ & (x, y, z), $\left(0, 0, \frac{\pi}{k}\right)$

$$\vec{E} = -\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)E_0 \text{ and } \vec{F} = \vec{E}q$$

Due to electric field $\vec{F} = -\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)q$

Hence net force is antiparallel to $\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$.

19. (*c*) Magnetic field when electromagnetic wave propagated in $+z$ direction

$$B = B_0\sin(kz - \omega t)$$

Where $B_0 = \frac{60}{3\times10^{8}} = 2\times10^{-7}\text{T}$

$$k = \frac{2\pi}{\lambda} = 0.5\times10^{3}$$

$$\omega = 2\pi f = 1.5\times10^{11}$$

20. (*c*) $\vec{E} = E_0\hat{n}\sin\left(\omega t + (6y - 8z)\right)$

$$= E_0\hat{n}\sin\left(\omega t + \vec{k}.\vec{r}\right)$$

where $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ and $\vec{k}\vec{r} = 6y - 8z$

$$\Rightarrow \vec{k} = 6\hat{j} - 8\hat{k}$$

Direction of propagation

$$\hat{s} = -\hat{k} = \left(\frac{-3\hat{j}+4\hat{k}}{5}\right)$$

21. (*c*) Ampere – Maxwell law

$$\rightarrow \oint\vec{B}.\vec{dl} = \mu_0 i_c + \mu_0\varepsilon_0\frac{d\phi_E}{dt}$$

Faraday law $\rightarrow \oint\vec{E}.\vec{dl} = \frac{d\phi_B}{dt}$

@FAKE_CBSE_X @RAJ_EDUNET

Gauss' law for electricity
$\rightarrow \oint \vec{E}\cdot\vec{dA} = \frac{Q}{\epsilon_0}$
Gauss 'law for magnetism
$\rightarrow \oint \vec{B}\cdot\vec{dA} = 0$

22. (c) According to Maxwell's eqn.
$\oint E\,dl = -\frac{\partial\phi_B}{\partial t}$

23. (a) Gauss's Law of electrostatic is,
$\oint \vec{E}\cdot d\vec{s} = \frac{q}{\epsilon_0}$

Faraday's law of EMI, $\oint \vec{E}\cdot d\vec{l} = \frac{-d\phi_B}{dt}$

Gauss's law of magnetism is, $\oint \vec{B}\cdot d\vec{A} = 0$
Ampere Maxwell law
$\oint \vec{B}\cdot d\vec{l} = \mu_0 i_C + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$

24. (d) Time constant,
$\tau = CR = \left(\frac{k\epsilon_0 A}{d}\right)\left(\rho\frac{d}{A}\right)\left[\because \ell = d\right]$
$= (\rho k\epsilon_0)$
For discharging RC-circuit
$q = q_0 e^{-t/\tau}$
$I = \frac{dq}{dt} = \frac{q_0}{\tau}e^{-t/\tau}$
$\therefore I = \frac{q_0}{\rho k\epsilon_0}e^{-t/\tau}$
Therefore, leakage current,
$I_{max} = \frac{q_0}{\rho k\epsilon_0} = \frac{2\times10^{-12}\times40}{200\times50\times8.85\times10^{-12}}$
$= 0.9\text{mA}$

25. (d) $\vec{E} = \hat{i}40\cos\omega\left(t-\frac{z}{c}\right)$
$\vec{v}$ is along +z direction
$\vec{E}$ is along +x direction
$\Rightarrow |\vec{B}| = \frac{E}{c}$ and its direction will be along +y. $\left[\text{As } \vec{C}\parallel\left(\vec{E}\times\vec{B}\right)\right]$
$\therefore \vec{B} = \hat{j}\frac{40}{c}\cos\omega\left(t-\frac{z}{c}\right)$

26. (a) Intensity $= \frac{1}{2}\varepsilon_0 E_0^2 c$
$= \frac{1}{2}\times9\times10^{-12}\times(600)^2\times3\times10^8$
$= \frac{9}{2}\times36\times3 = 486\text{ w/m}^2$

27. (b) $E = Bc \Rightarrow 60 = B\times3\times10^8$
$\Rightarrow B = 2\times10^{-7}$
$\Rightarrow 3\times10^8 = f\times4\times10^{-3}$ [As, $c = f\lambda$]
$\Rightarrow f = \frac{3}{4}\times10^{11}$
$\Rightarrow \omega = 2\pi f = \frac{3}{4}\times2\pi\times10^{11}$
$\Rightarrow \omega = \frac{\pi}{2}\times10^{11}\text{C}$
As $\vec{C} = \vec{E}\times\vec{B}$
Hence, electric field will be in y direction and magnetic field in z direction.

28. (b) Here, we have
$E_0 = B_0 c$
$E_0 = 3\times10^8\times(3.5\times10^{-7}) = 105$
$E_0 = 105\sin(1.5\times10^7 x + 0.5\times10^{11} t)\text{ Vm}^{-1}$
It is given that magnetic field is along y direction, by assuming the speed of light in x- direction, the electric field will be in z - direction.

29. (b) Intensity of the wave
$I = \frac{1}{2}\epsilon_0 E_0^2 \times c$
$I = \frac{1}{2}\times8.85\times10^{-12}\times4\times10^4\times3\times10^8$
$= 53.1\text{ W/m}^2$

30. (a) $\frac{E}{B} = C$
$\frac{E}{B} = 3\times10^8$
The value of magnetic field
$B = \frac{E}{3\times10^8} = \frac{9.6}{3\times10^8}$
$B = 3.2\times10^{-8}\text{ T}$
$\hat{B} = \hat{V}\times\hat{E} = \hat{i}\times\hat{j} = \hat{k}$
So, $\vec{B} = 3.2\times10^{-8}\hat{k}T$

31. (b) Given $\vec{E} = E_0\cos(\omega t - kz)\hat{i}$
As we know that, $B = \frac{B}{C}$
And, $\hat{C} = \hat{E}\times\hat{B}$
Hence, $\vec{B} = \frac{E_0}{C}\cos(\omega t - kz)\hat{j}$

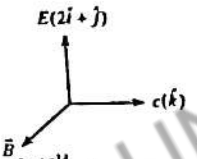
32. (c) Given: $f = 60\text{MHz}$
$\lambda = \frac{c}{f} = \frac{3\times10^8}{60\times10^6} = 5\text{m}$

33. (b) $\vec{E} = 6.6\hat{j}$, $v = 20\text{ MHz}$, $\vec{c} = 3\times10^8\hat{i}$
From, $C = \frac{|E|}{|B|}$.
$|\vec{B}| = \frac{|\vec{E}|}{c} = \frac{6.6}{3\times10^8}\times2.2\times10^{-8}T$
For direction
$\hat{E}\times\hat{B} = \hat{c}$
$\hat{i}\times\hat{B} = \hat{i} \Rightarrow \hat{B} = \hat{k}$
$\vec{B} = 2.2\times10^{-8}\hat{k}T$

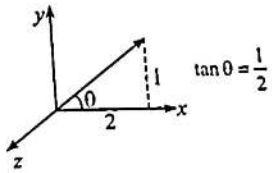
34. (b) $\because C = \frac{E_0}{B_0}$
$3\times10^8 = \frac{E_0}{6\times10^{-7}}$
$E_0 = 180\text{ Vm}^{-1}$

35. (a) $\because C = \frac{\omega}{k} \Rightarrow \frac{\omega}{k} = \frac{E_0}{B_0}$

36. (a) EM waves are neutral and
$E_0 = \sqrt{\frac{1}{\mu_0\epsilon_0}}B_0$
Statement-I is correct and
Statement-II is wrong.

37. (a, d)


$c_{med.} = \frac{5\times10^{14}}{10^7/3} = 1.5\times10^8\,m/s$
Reflective index
$\mu = \frac{c}{c_{med.}} = \frac{3\times10^8}{1.50\times10^8} = 2$
$c_{med.} = \frac{|E|}{|B|} \Rightarrow |B| = \frac{|E|}{c_{med.}} = \frac{30\sqrt{5}}{1.5\times10^8}$
$= 2\sqrt{5}\times10^{-7}$
$\hat{B}_{direction} = \hat{k}\times(2\hat{i}+\hat{j}) = \frac{2\hat{j}-\hat{i}}{\sqrt{5}}$
$\therefore \vec{B} = 2\times10^{-7}(-\hat{i}+2\hat{j})\sin\left[27\left(5\times10^{17}t - \frac{10^7}{3}z\right)\right]$



$\tan\theta = \frac{1}{2}$

38. (c) $E_0 = B_0 c = 2\times10^{-8}\times3\times10^8 = 6\text{V/m}$
Since, $B \rightarrow \hat{j}$ and $v \rightarrow \hat{i}$
Therefore, $E \rightarrow \hat{k}$
Direction will be along z-axis

39. (d) We have, $B_y = 5\times10^{-6}\sin 100p\,(5x - 4\times10^8 t)T$. On comparing with standard equation, $B = B_0\sin(wt + kx)$, we get
$B_0 = 5\times10^{-6}$
Speed of wave, $v = \frac{4\times10^8}{5} = 8\times10^7$ $\left[\because v = \frac{\omega}{K}\right]$
$E_0 = V\times B_0 = 8\times10^7\times5\times10^{-6} = 4\times10^2\text{ Vm}^{-1}$

@FAKE_CBSE_@RAJ_EDUNET

40. (a) Given, $E_y = 540\sin\pi\times10^4(x-ct)\ \text{Vm}^{-1}$
$\therefore E_0 = 540\ \text{Vm}^{-1}$
$$c = \frac{E_0}{B_0} \Rightarrow B_0 = \frac{E_0}{c} = \frac{540}{3\times10^8} = 18\times10^{-7}\ \text{T}$$

41. (c) $c' = \frac{c}{\sqrt{\mu_r\varepsilon_r}}$
$B = \mu_0 \times \mu_r H$
$E = Bc'$

42. (c) $c = \frac{E}{B} \Rightarrow E = cB = 24\ V/m$
As we know that direction of propagation of wave
$\hat{E}\times\hat{B} = \hat{c}$, so $\hat{E} = -\hat{x}$, hence
$\vec{E} = -24\hat{x}\ V/m$

43. (b) $\vec{E}$ is perpendicular to $\vec{B}$.
$E = cB = 3\times10^8\times2\times10^{-8} = 6\ \text{V/m}$

44. (d) We know that,
$$\frac{E_0}{B_0} = C \Rightarrow B_0 = \frac{E_0}{c} = \frac{800}{3\times10^8}T$$
$$F_{max} = qvB_0$$
$$= 1.6\times10^{-19}\times3\times10^7\times\frac{800}{3\times10^8}$$
$$12.8\times10^{-18}\ \text{N}$$

45. (c) $\hat{k} = \hat{E}\times\hat{B}$

46. [2] We know that,
$Bc = E$
$$\Rightarrow B = \frac{E}{c} = \frac{6}{3\times10^8} = 2\times10^{-8}T$$
$\Rightarrow x = 2$
Hence, $x = 2$ is the correct answer.

47. (c)
$$\vec{F}_{q_1} = q\left(\vec{V}\times\vec{B}\right)$$
$$= 4\pi\left(0.5c\hat{i}\right)\times\frac{B_0}{\sqrt{2}}\begin{pmatrix}\cos(kz-\omega t)\\ \hat{i}+\cos(kz-wt)\hat{j}\end{pmatrix}$$
$$= 4\pi(0.5c)\left(\frac{B_0}{\sqrt{2}}\right)\cos\left(k\frac{\pi}{k}\right)\hat{k}$$
$$\vec{F}_{q_2} = q\left(\vec{V}\times\vec{B}\right)$$
$$= 2\pi\left(0.5c\hat{i}\right)\times\frac{B_0}{\sqrt{2}}\begin{pmatrix}\cos(kz-\omega t)\\ \hat{i}+\cos(kz-wt)\hat{j}\end{pmatrix}$$
$$= 2\pi(0.5c)\left(\frac{B_0}{\sqrt{2}}\right)\cos\left(k\frac{3\pi}{k}\right)\hat{k}$$
So $\frac{F_1}{F_2} = 2:1$

48. (b) $\vec{E}\times\vec{B} \parallel \vec{C}$
Hence $\vec{B}$ should be in $\hat{k}$ direction.
Also, $E_0 = B_0C$, $C = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$
$$\Rightarrow \vec{B} = E_0\sqrt{\mu_0\varepsilon_0}\cos(kx)\hat{k}$$

49. (c) $\vec{B} = 1.2\times10^{-7}\sin(0.5\times10^3x + 1.5\times10^{11}t)\hat{k}]\ T.$
Wave is travelling along $-x$ axis and $\vec{B}$ is along $+z$ axis.
$$E_0 = cB_0 = 36\frac{V}{m}$$
$\vec{E}$ must be along $-y$ axis

50. (c) $\frac{E}{B} = c$
$B = B\times c = 15\ \text{N/C}$

51. (b) $E_0 = B_0C = 3\times10^8\times3\times10^{-8} = 9\ \text{V/m}$
Pointing vector $\vec{s} = \frac{\vec{E}\times\vec{B}}{\mu_0}$
$\therefore E = -9\sin[200\pi(y+ct)]\ \hat{k}$
(along $-$ve z-axis)

52. (d) The ratio of maximum electric field to maximum magnetic field.
$$\frac{E_0}{B_0} = c \quad B_0 = \frac{E_0}{c}$$
Force, $F_{max} = QVB$ [Q is charge, V is speed and B is magnetic field]
$$F = 1.6\times10^{-19}\times(0.1c)\times\frac{E_0}{c} = 4.8\times10^{-19}\ N$$

53. (c) $\vec{E}\times\vec{B}$ is along $\vec{C}$
$\hat{E}\times\hat{B} = \hat{C}$
$$\Rightarrow \vec{B} = \frac{E_0}{c}(-\hat{x}+\hat{y})\sin(kz-\omega t)$$

54. (d) $\frac{E_0}{B_0} = c$ (speed of light in vacuum)
$E_0 = B_0c = 3\times10^{-8}\times3\times10^8 = 9\ \text{N/C}$
So $\vec{E} = 9\sin(1.6\times10^3x + 48\times1010t)\ \hat{k}$ v/m

55. (c) $\hat{C} = \hat{E}\times\hat{B}$
$$= \hat{k}\times\frac{(\hat{i}-\hat{j})}{\sqrt{2}} = \frac{(\hat{i}+\hat{j})}{\sqrt{2}}$$
$$= \frac{E_0}{c}i\cos(ky-\omega t)$$

56. (a) Magnetic field vectors associated with this electromagnetic wave are given by
$$\vec{B}_1 = \frac{E_0}{c}\hat{k}a\cos(kx-\omega t)\ \&\ B_2$$
$$\vec{F} = q\vec{E} + q(\vec{V}\times\vec{B})$$
$$= q(\vec{E}_1+\vec{E}_2) + q(\vec{V}\times(\vec{B}_1+\vec{B}_2))$$
by putting the value of $\vec{E}_1, \vec{E}_2, \vec{B}_1$ & $\vec{B}_2$
The net Lorentz force on the charged particle is
$$\vec{F} = qE_0[0.8\cos(kx-\omega t)\hat{i} + \cos(kx-\omega t)\hat{j} + 0.2\cos(kx-\omega t)\hat{k}]$$
at $t = 0$ and at $x = y = 0$
$$\vec{F} = qE_0[0.8\hat{i} + \hat{j} + 0.2\hat{k}]$$

57. (b) $\because \vec{E}\times\vec{B} \parallel \vec{v}$
Given that wave is propagating along positive z-axis and $\vec{E}$ along positive x-axis. Hence $\vec{B}$ long y-axis.
From Maxwell equation
$$\frac{\partial E}{\partial z} = -\frac{\partial B}{\partial t} \text{ and } B_0 = \frac{E_0}{c}$$
Option (b) is correct

58. (b) $\frac{E}{B} = c$

59. (d) $E = cB$
$E = 3\times10^8\times1.6\times10^{-8}\times\sqrt{5}$
$E = 4.8\times10^2\sqrt{5}$
Direction of electric field is along $(-\hat{i}+2\hat{j})$
$\therefore \vec{E} = 4.8\times10^2\cos(2\times10^7z + 6\times10^{15}t)(-\hat{i}+2\hat{j})\frac{V}{m}$

60. (c) The direction of propagation of an EM wave is direction $\vec{E}\times\vec{B}$.
$\hat{i} = \hat{j}\times\hat{B} \Rightarrow \hat{B} = \hat{k}$
$$c = \frac{E}{B} \Rightarrow B = \frac{E}{c} = \frac{6}{3\times10^8}$$
$B = 2\times10^{-8}$ T along z-direction.

61. (d) Maximum Electric field $E = (B)(c)$
$\vec{E}_0 = (3\times10^{-5})c(-\hat{j})$
$\vec{E}_1 = (2\times10^{-6})c(-\hat{i})$
$\vec{F}_{net} = q\vec{E} = qc(-3\times10^{-5}\hat{j} - 2\times10^{-6}\hat{i})$
$\vec{F}_{max} = 10^{-4}\times3\times10^8\sqrt{(3\times10^{-5})^2 + (2\times10^{-6})^2}$
$= 0.9\ \text{N}$
$$F_{rms} = \frac{F}{\sqrt{2}} = 0.6\ \text{N (approx)}$$

62. (d) $\vec{E} = 10\hat{j}\cos(6x+8z-10ct)$
$$B_0 = \frac{E_0}{c} = \frac{10}{c}$$
$\omega = 10\ c$
$\because \hat{E}\times\hat{B} = \hat{C}$
$$\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 0 & 1 & 0\\ B_x & B_y & B_z\end{vmatrix} = \frac{6\hat{i}+8\hat{j}}{10}$$
$$\Rightarrow B_z\hat{i} - 0\hat{j} - B_x\hat{k} = \frac{3}{5}\hat{i} + \frac{4}{5}\hat{j}$$
$$\Rightarrow B_z = \frac{3}{5}, B_y = 0, B_z = \frac{4}{5}$$
$$\therefore \vec{B} = \frac{1}{C}\left(-8\hat{i}+6\hat{k}\right)\cos(6x+8z+10ct)$$

@FAKE_CBSE_X @RAJ_EDUNET

$\vec{E}\times\vec{B}\parallel\vec{v}$
that wave is propagating along
ve z-axis and $\vec{E}$ along positive
Hence $\vec{B}$ long y-axis.
Maxwell equation
$\frac{\partial B}{dt}$ and $B_0=\frac{E_0}{c}$
(b) is correct

c

B

$0^8\times1.6\times10^{-6}\times\sqrt{5}$
$10^2\sqrt{5}$

of electric field is along

$:10^2\cos(2\times10^7z+6\times10^{15}t)$
$(-\hat{i}+2\hat{j})\frac{V}{m}$

:tion of propagation of an EM
:tion $\vec{E}\times\vec{B}$.
$\hat{B}=\hat{k}$

$=\frac{E}{c}=\frac{6}{3\times10^8}$

along z-direction.
Electric field $E=(B)(c)$
$)c\left(-\hat{j}\right)$

$c\left(-\hat{i}\right)$

$-3\times10^{-5}\hat{j}-2\times10^{-4}\hat{i}\right)$
$0^8\sqrt{\left(3\times10^{-5}\right)^2+\left(2\times10^{-4}\right)^2}$
$=0.9\,N$

N (approx)

$5x+8z-10ct)$

$\frac{+8\hat{j}}{10}$

$:\frac{3}{5}\hat{i}+\frac{4}{5}\hat{j}$

$\frac{}{z}=\frac{4}{5}$

$\cos(6x+8z+10ct)$

64. (c) $\frac{E_i}{B_i}=c$ ...(i)

$\frac{E_f}{B_f}=\frac{c}{n}$ ...(ii)

$\Rightarrow\frac{E_iB_f}{E_fB_i}=n\Rightarrow\frac{E_i}{E_f}=n\frac{B_i}{B_f}$

Hence ratio will be $\sqrt{n}:\frac{1}{\sqrt{n}}$

64. (b) $E=cB$

65. (d) $\because\ \epsilon_r\times\mu_r=\frac{c^2}{v^2}$

$\epsilon_r\times2=\frac{(3\times10^8)^2}{(1.5\times10^8)^2}\Rightarrow\epsilon_r=2$

66. (b) Pressure $=\frac{I}{C}=\frac{F}{A}$

[where F is force and A is area]

$\Rightarrow\frac{360}{10^{-4}\times3\times10^8}=\frac{2.4\times10^{-4}}{A}$

$\Rightarrow A=2\times10^{-2}\,m^2=0.02\,m^2$

67. (a) Energy density, $U_E=\frac{1}{2}\epsilon_0E^2$

$U_E=\frac{1}{2}\times8.85\times10^{-12}\times(50)^2$

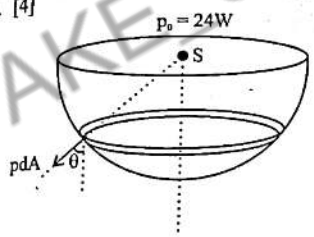
$=1.106\times10^{-8}\,J/m^3$

68. (b) Energy density due to electric field and magnetic field,

$\frac{1}{2}\varepsilon_0E^2=\frac{B^2}{2\mu_0}$

$\because E=CB$ and $C=\frac{1}{\mu_0\varepsilon_0}$

69. [4]



Force $=\int PdA\cos\theta$

$=\frac{2I}{C}\int dA\cos\theta=\frac{2I}{C}\pi R^2=2\frac{p_0}{4\pi R^2}\cdot\frac{\pi R^2}{C}$

$=\frac{p_0}{2C}=\frac{24}{2\times3\times10^8}=4\times10^{-8}\,N$

70. (a) Electric energy density $=\frac{1}{2}\epsilon_0E_{rms}^2$

Magnetic energy density $=\frac{B_{rms}^2}{2\mu_0}$

$\therefore\frac{\text{Electric energy density}}{\text{Magnetic energy density}}=\frac{\frac{1}{2}\epsilon_0E_{rms}^2}{\left(\frac{B_{rms}^2}{2\mu_0}\right)}$

$=\left(\frac{E_{rms}}{B_{rms}}\right)^2\cdot\mu_0\epsilon_0\quad\left[\because c=\frac{1}{\sqrt{\mu_0\epsilon_0}}\right]$

$\left(\frac{E_0}{\sqrt{2}}\times\frac{\sqrt{2}}{B_0}\right)^2\cdot c^2=\frac{c^2}{c^2}=1\quad\left[\because\frac{E_0}{B_0}=C\right]$

71. (c) $\vec{E}=20\sin\omega\left(t-\frac{x}{C}\right)\hat{j}N/C$

Comparing with

$E=E_0\sin\omega\left(t-\frac{x}{c}\right)\hat{j}N/C$

$E_0=20\,N/C$

Average energy density of an em wave

Then Energy stored $=\frac{1}{2}\epsilon_0E_0^2\times(\text{volume})$

$=\frac{1}{2}\times8.85\times10^{-12}\times(20)^2\times\left(5\times10^{-4}\right)J$

$=...8.85\times10^{-13}J$

72. (c) Frequency of Energy of electromognetic wave has double value than frequency of wave.

73. (d) Average electric energy density is equal to average magnetic energy density,

$\Rightarrow\langle u_E\rangle=\langle u_B\rangle=\frac{1}{2}\langle u_{total}\rangle$

$\Rightarrow\frac{u_E}{u_{total}}=\frac{1}{2}$

74. (b) $I_{EF}=\frac{1}{2}\times\frac{100\times5\%}{4\pi(5)^2}=\frac{1}{2}\times\frac{5}{4\pi\times5^2}$

$=\frac{1}{40\pi}W/m^2$

75. (b) $I=\frac{1}{2}\varepsilon_0E_0^2c$

76. (d) $A=36cm^2=36\times10^{-4}m^2$

$<F>7.2\times10^{-9}N$, $t=20$ min

$<F>=\frac{\Delta P}{\Delta t}=\frac{E}{C\Delta t}$

$\Rightarrow\frac{E}{A\Delta t}=\frac{<F>c}{A}=\frac{7.2\times10^{-9}\times3\times10^8}{36}$

$=0.06\,W/cm^2$

77. [43] $I=\left(\frac{1}{2}\varepsilon_0E_0^2\right)C\Rightarrow E_0=\sqrt{\frac{2I}{\varepsilon_0C}}$

$B=\frac{E_0}{C}$

78. (b) Fact based

79. [25]

$F=\frac{IA}{C}\therefore I=\frac{Fc}{A}=\frac{2.5\times10^{-6}\times3\times10^8}{30}$

$=25W/cm^2$

80. [3] $I=\frac{1}{2}c\,e_0\,E^2$

$E^2\propto I$

$I=\frac{\text{Power}}{\text{Area}}$

$E^2\propto\frac{P}{A}$

$E\propto\sqrt{P}$

$\frac{E'}{E}=\sqrt{\frac{60}{100}}$

$E'=\sqrt{\frac{3}{5}}E$

So the value of x = 3

81. [137] Intensity of the electromagnetic wave

$I=\frac{1}{2}c\varepsilon_0E_0^2=\eta\times\left(\frac{P}{4\pi r^2}\right)$ Here η is the efficiency

$E_0=\sqrt{\frac{\eta P}{2\pi r^2c\varepsilon_0}}$

$=\sqrt{\frac{1.25}{100}\times\frac{1000}{2\times3.14\times4\times3\times10^8\times8.85\times10^{-12}}}$

$E_0=\sqrt{\frac{\eta P}{2\pi r^2c\varepsilon_0}}$

$=\sqrt{\frac{1.25}{100}\times\frac{1000}{2\times3.14\times4\times3\times10^8\times8.85\times10^{-12}}}$

Hence, value of x is 136.9

82. [500] Electric field in an electromagnetic field,

$E=50\,N/s\sin\omega(t-x/c)$

Energy $=5.5\times10^{-12}J$, Vol., $V=?$

$u=\frac{1}{2}\varepsilon_0E^2\rightarrow$ energy density

$\because u=\frac{U}{V}\Rightarrow U=uV$

$=\frac{1}{2}\varepsilon_0E^2\cdot V$

$5.5\times10^{-12}=\frac{1}{2}\times8.85\times10^{-12}\times50^2\times V$

$V=\frac{5.5\times10^{-12}\times2}{8.55\times2500\times10^{-12}}\times10^6\ cm^3$

$=0.0497\times10^4=497$

$\cong500\ cm^3$

Hence, volume 500 is cm^3.

83. [2] $I=\frac{1}{2}c\varepsilon_0E_0^2\Rightarrow\frac{8}{4\pi(10)^2}\times\frac{1}{2}$

$=\frac{1}{4}\times c\times\frac{1}{c^2\mu_0}\times E_0^2$

$\Rightarrow E_0=\frac{2}{10}\sqrt{\frac{\mu_0c}{\pi}}\Rightarrow x=2$

@FAKE_CRSE_V@MAJ_EDUNET

84. (*d*) Intensity,

$$I=\frac{1}{2}C\varepsilon_0E_0^2=\frac{1}{2}C\varepsilon_0(CB_0)^2=\frac{1}{2}C^3\varepsilon_0B_0^2$$

$$\therefore \text{Magnetic field, } B_0=\sqrt{\frac{2I}{\varepsilon_0C^3}}$$

$$=\sqrt{\frac{2\times0.092}{8.85\times10^{-12}\times27\times10^{24}}}=\sqrt{\frac{0.184}{229.5\times10^{12}}}$$

$$=2.27\times10^{-8}\text{T}$$

85. (*d*) $\frac{B^2}{2\mu_0}=1.02\times10^{-8}\Rightarrow B^2$

$$=(1.02\times10^{-8})\times2\,\mu_0$$

Also, $\frac{1}{\sqrt{\mu_0\varepsilon_0}}=C\Rightarrow\mu_0=\frac{1}{C^2\varepsilon_0}$

$$\Rightarrow B^2=(1.02\times10^{-8})\,2\times\frac{4\pi\times9\times10^9}{9\times10^{16}}$$

$$\Rightarrow B=160\text{ nT}$$

86. [194] We have given that the in tensity of laser in

$$\left(\frac{315}{\pi}\right)w/m^2$$

$$\because I=\frac{1}{2}\varepsilon_0E_0^2C$$

$$\Rightarrow E_0=\sqrt{\frac{2I}{\varepsilon_0c}}$$

$$\therefore E_{rms}=\frac{E_0}{\sqrt{2}}=\sqrt{\frac{1}{\varepsilon_0c}}$$

$$=\sqrt{\frac{315}{\pi}\times\frac{1}{8.86\times8.86\times10^{-12}\times3\times10^8}}=194$$

87. (*b*) Magnetic energy density $\frac{B^2}{2\mu_0}$

$$\frac{\text{Displacement}\times\text{force}}{(\text{Displacement})^3}=\frac{L.MLT^{-2}}{L^3}$$

$$(ML^{-1}T^{-2})$$

88. (*d*) $B=\frac{E}{c}$

$$\Rightarrow U_E=\frac{1}{2}\varepsilon_0E^2$$

$$U_B=\frac{B^2}{2\mu_0}=\frac{E^2}{2\mu_0c^2}=\frac{E^2}{2\mu_0}(\mu_0\varepsilon_0)=U_E$$

89. (*d*) Intensity of EM wave is given by

$$I=\frac{\text{Power}}{\text{Area}}=\frac{1}{2}\varepsilon_0E_0^2C$$

$$=\frac{27\times10^{-3}}{10\times10^{-6}}=\frac{1}{2}\times9\times10^{-2}\times E^2\times3\times10^8$$

$$E=\sqrt{2}\times10^3\text{ kV/mn}=1.4\text{ kV/m}$$

90. (*d*) $\because I=\frac{B_0^2c}{2\mu_0}$

$$\Rightarrow B_0=\sqrt{\frac{I2\mu_0}{c}}$$

$$\Rightarrow B_0=\sqrt{\frac{10^8\times2\times4\pi\times10^{-7}}{3\times10^8}}=10^{-4}\text{T}$$

91. (*c*) $\lambda_1<\lambda_2<\lambda_3<\lambda_4$

92. (*b*) gamma rays are most energetic thus having smallest wavelength (λ). Infrared is the least energetic thus having biggest wavelength (λ).

93. (*b*) Increasing order of wave length

Micro wave	0.1 m to 1 mm
Infra red	1 mm to 700 nm
Ultra Violet	400 nm to 1 nm
X-ray	1 nm to 10^{-3} nm

94. (*b*) Based on theory.

95. (*c*) Microwaves are used for aircraft navigation. IR is used for physiotherapy. X-rays are used for cancer treatment. UV rays are used for Lasik eye surgery.

96. (*a*) Fact based

97. (*b*) From electromagnetic wave spectrum

98. (*b*) Based an theoretical data.

99. (*c*) Fact based.

100. (*a*) Here, we have

$$E_{\gamma\text{-Rays}}>E_{X\text{-Rays}}>E_{\text{microwave}}>E_{\text{AM Radiowaves}}$$

$$\therefore \lambda_{\gamma\text{-Rays}}<\lambda_{X\text{-Rays}}<\lambda_{\text{microwave}}<\lambda_{\text{AM Radiowaves}}$$

(a) Microwave	→	(iv) 10^{-3} m
(b) Gamma Rays	→	(ii) 10^{-15} m
(c) AM Radio wve	→	(i) 100 m
(d) X-Rays	→	(iii) 10^{-10} m

101. (*c*) Fact based

JEE-Advanced

1. (*a, d*) Speed of light in medium is $V=\frac{\omega}{k}$

$$V=\frac{3\times5\times10^{14}}{10^7}$$

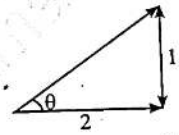
$$V=1.5\times10^8$$

$$\text{Refractive index } \mu=\frac{C}{V}=\frac{3\times10^8}{1.5\times10^8}=2$$

$$\mu=2$$

$$\text{Given } \vec{E}=30(2\hat{x}+\hat{y})$$

$$\sin\left(2\pi\left(5\times10^{14}t-\frac{10^7}{3}2\right)\right)^{1/m}$$



$$\tan\theta=\frac{1}{2}$$

$$B_0=\frac{E_0}{V}=\frac{30\sqrt{5}}{1.5\times10^8}$$

Direction of $\vec{B}_0$ is $(\vec{V}\times\vec{E})$

$$\vec{V}\times\vec{E}$$

$$=\hat{k}\times\frac{(2\hat{i}+\hat{j})}{\sqrt{5}}$$

$$\left(\frac{-\hat{i}+2\hat{j}}{\sqrt{5}}\right)\text{ put value}$$

$$\vec{B}_0=\frac{30\sqrt{5}}{1.5\times10^8}\left(\frac{-\hat{i}+2\hat{j}}{\sqrt{5}}\right)$$

$$B_x=-2\times10^7$$

@FAKE_CBSE_X_@RAJ_ERUNET

Ray Optics and Optical Instruments

Scan for Ⓟ Sol

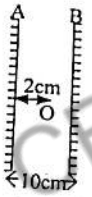
JEE-Main

Plane Mirror

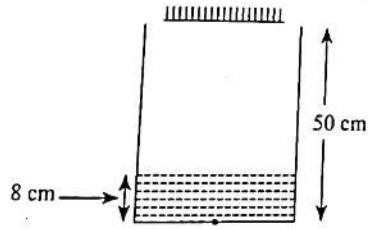
1. The light rays from an object have been reflected towards an observer from a standard flat mirror, the image observed by the observer are:
A. Real B. Erect
C. Smaller in size then object D. Laterally inverted
Choose the most appropriate answer from the options given below:
(a) B and D only (b) B and C only
(c) A and D only (d) A, C and D only
[25 Jan, 2023 (Shift-II)]

2. An object is placed at a distance of 12 cm in front of a plane mirror. The virtual and erect image is formed by the mirror. Now the mirror is moved by 4 cm towards the stationary object. The distance by which the position of image would be shifted, will be: **[10 Apr, 2023 (Shift-I)]**
(a) 4 cm towards mirror (b) 8 cm towards mirror
(c) 8 cm away from mirror (d) 2 cm towards mirror

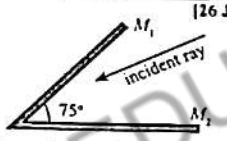
3. Two vertical parallel mirrors A and B are separated by 10 cm. A point object O is placed at a distance of 2 cm from mirror A. The distance of the second nearest image behind mirror A from the mirror A is ____ cm
[8 Apr, 2023 (Shift-I)]



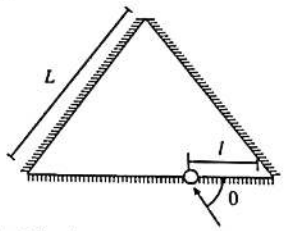
4. As shown in the figure, a plane mirror is fixed at a height of 50 cm from the bottom of tank containing water $\left(\mu = \frac{4}{3}\right)$. The height of water in the tank is 8 cm. A small bulb is placed at the bottom of the water tank. The distance of image of the bulb formed by mirror from the bottom of the tank is _____ cm. **[11 Apr, 2023 (Shift-II)]**



5. A light ray is incident, at an incident angle θ_1, on the system of two plane mirrors M_1 and M_2 having an inclination angle 75° between them (as shown in figure). After reflecting from mirror M_1 it gets reflected back by the mirror M_1 with an angle of reflection θ_2. The total deviation of the ray will be _____ degree.
[26 June, 2022 (Shift-I)]



6. Three plane mirrors from an equilateral triangle with each side of length L. There is a small hole at distance $l > 0$ from one of the corners as shown in th figure. A ray of light is passed through the hole at an angle θ and can only come out through the same hole. The cross section of the mirror configuration and the ray of light lie on the same plane. **(2022)**

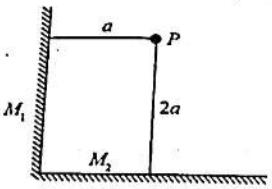


Which of the following statement(s) is (are) correct?
(a) The ray of light will come out for $\theta = 30°$, for $0 < l < L$.
(b) There is an angle for $l = \frac{L}{2}$ at which the ray of light will come out after two reflections.
(c) The ray of light will NEVER come out for $\theta = 60°$, and $l = \frac{L}{3}$
(d) The ray of light will come out for $\theta = 60°$, and $0 < l < \frac{L}{2}$ after six reflections.

7. The incident ray, reflected ray and the outward drawn normal are denoted by the unit vectors $\vec{a}, \vec{b}$ and $\vec{c}$ respectively. Then choose the correct relation for these vectors. **[26 Feb, 2021 (Shift-II)]**
(a) $\vec{b} = \vec{a} - \vec{c}$ (b) $\vec{b} = \vec{a} + 2\vec{c}$
(c) $\vec{b} = 2\vec{a} + \vec{c}$ (d) $\vec{b} = \vec{a} - 2(\vec{a}\cdot\vec{c})\vec{c}$

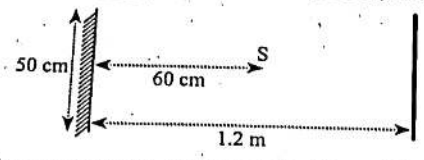
@FAKE_CBSE_X@RKFUNET

8. Two plane mirrors M_1 and M_2 are at right angle to each shown. A point source 'P' is placed at 'a' and '$2a$' meter away from M_1 and M_2 respectively. The shortest distance between the images thus formed is : (Take $\sqrt{5} = 2.3$) **[31 Aug, 2021 (Shift-I)]**

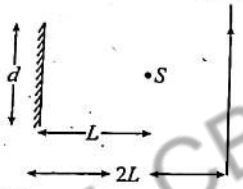


(a) $2\sqrt{10}\,a$ (b) $2.3\,a$ (c) $4.6\,a$ (d) $3\,a$

9. A point source of light S, placed at a distance 60 cm infront of the centre of a plane mirror of width 50 cm, hangs vertically on a wall. A man walks infront of the mirror along a line parallel to the mirror at a distance 1.2 m from it (see in the figure). The distance between the extreme points where he can see the image of the light source in the mirror is _____ cm. **[26 Feb, 2021 (Shift-II)]**



10. A point source of light, S is placed at a distance L in front of the centre of plane mirror of width d which is hanging vertically on a wall. A man walks in front of the mirror along a line parallel to the mirror, at a distance $2L$ as shown below. The distance over which the man can see the image of the light source in the mirror: **[12 Jan, 2019 (Shift-I)]**



(a) d (b) $2d$ (c) $3d$ (d) d

11. Two plane mirrors are inclined to each other such that a ray of light incident to the first mirror (M_1) and parallel to the second mirror (M_2) is finally reflected from the second mirror (M_2) parallel to the first mirror (M_1). The angle between the two mirrors will be: **[9 Jan, 2019 (Shift-II)]**

(a) 45° (b) 60° (c) 75° (d) 90°

Spherical Mirrors

12. A convex mirror of radius of curvature 30 cm forms an image that is half the size of the object. **[29 Jan, 2024 (Shift-I)]**

The object distance is:

(a) −15 cm (b) 45 cm (c) −45cm (d) 15 cm

13. If the distance between object and its two times magnified virtual image produced by a curved mirror is 15 cm, the focal length of the mirror must be: **[29 Jan, 2024 (Shift-II)]**

(a) 15 cm (b) −12 cm (c) −10 cm (d) 10/3 cm

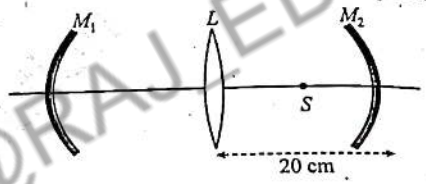
14. Two objects A and B are placed at 15 cm and 25 cm from the pole in front of a concave mirror having radius of curvature 40 cm. The distance between images formed by the mirror is: **[1 Feb, 2023 (Shift-II)]**

(a) 40 cm (b) 60 cm (c) 160 cm (d) 100 cm

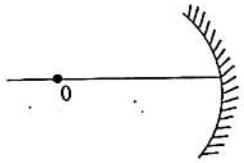
15. A thin cylindrical rod of length 10 cm is placed horizontally on the principle axis of a concave mirror of focal length 20 cm. The rod is placed in a such a way that mid point of the rod is at 40 cm from the pole of mirror. The length of the image formed by the mirror will be $\frac{x}{3}$ cm. The value of x is _____. **[1 Feb, 2023 (Shift-I)]**

16. In an experiment for estimating the value of focal length of converging mirror, image of an object placed at 40 cm from the pole of the mirror is formed at distance 120 cm from the pole of the mirror. These distances are measured with a modified scale in which there are 20 small divisions in 1 cm. The value of error in measurement of focal length of the mirror is 1/K cm. The value of K is _____. **[30 Jan, 2023 (Shift-I)]**

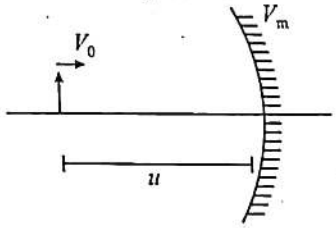
17. An optical arrangement consists of two concave mirrors M_1 and M_2 and a convex lens L with a common principal axis, as shown in the figure. The focal length of L is 10 cm. The radii of curvature of M_1 and M_2 are 20 cm and 24 cm, respectively. The distance between L and M_2 is 20 cm. A point object S is placed at the mid-point between L and M_2 on the axis. When the distance between L and M_1 is n/7 cm, one of the images coincides with S. The value of n is _____. **[JEE Adv, 2023]**



18. An object 'O' is placed at a distance of 100 cm in front of a concave mirror of radius of curvature 200 cm as shown in the figure. The object starts moving towards the mirror at a speed 2 cm/s. The position of the image from the mirror after 10 s will be at _____ cm. **[28 July, 2022 (Shift-II)]**



19. An object and a concave mirror of focal length $f = 10$ cm both move along the principal axis of the mirror with constant speeds. The object moves with speed $V_0 = 15\ cm\ s^{-1}$ towards the mirror with respect to a laboratory frame. The distance between the object and the mirror at a given moment is denoted by u. When $u = 30$ cm, the speed of the mirror V_m is such that the image is instantaneously at rest with respect to the laboratory frame, and the object forms a real image. The magnitude of V_m is _____ cms^{-1}. **[JEE Adv, 2022]**



@NAKE_CBSE X @RAJ EDUSET

20. A short straight object of height 100 cm lies before the central axis of a spherical mirror whose focal length has absolute value $|f| = 40$ cm. The image of object produced by the mirror is of height 25 cm and has the same orientation of the object. One may conclude from the information: **[26 Feb, 2021 (Shift-I)]**

(a) Image is virtual, opposite side of concave mirror.
(b) Image is real, same side of convex mirror.
(c) Image is real, same side of concave mirror.
(d) Image is virtual, opposite side of convex mirror.

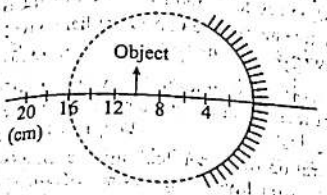
21. The focal length f is related to the radius of curvature r of the spherical convex mirror by: **[24 Feb, 2021 (Shift-I)]**

(a) $f = r$ (b) $f = -\frac{1}{2}r$

(c) $f = -r$ (d) $f = +\frac{1}{2}r$

22. An object is placed beyond the centre of curvature C of the given concave mirror. If the distance of the object is d_1 from C and the distance of the image formed is d_2 from C, the radius of curvature of this mirror is : **[27 Aug, 2021 (Shift-I)]**

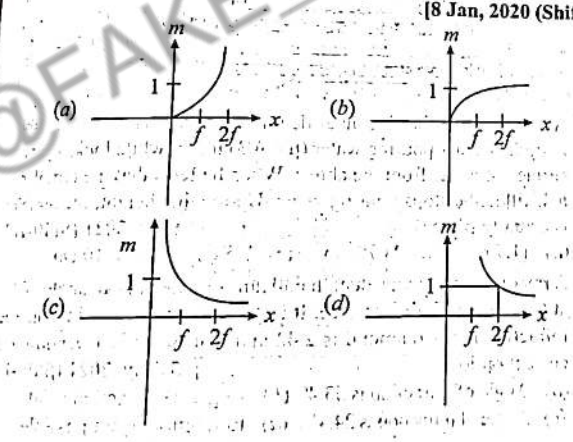
(a) $\frac{2d_1d_2}{d_1+d_2}$ (b) $\frac{d_1d_2}{d_1+d_2}$ (c) $\frac{2d_1d_2}{d_1-d_2}$ (d) $\frac{d_1d_2}{d_1-d_2}$

23. 

A spherical mirror is obtained as shown in the figure from a hollow glass sphere. if an object is positioned infront of the mirror, what will be the nature and magnification of the image of the object? (Figure drawn as schematic and not to scale) **[2 Sep, 2020 (Shift-I)]**

(a) Inverted, real and magnified
(b) Erect, virtual and unmagnified
(c) Inverted, real and unmagnified
(d) Erect, virtual and magnified

24. An object is gradually moving away from the focal point of a concave mirror along the axis of the mirror. The graphical representation of the magnitude of linear magnification (m) versus distance of the object from the mirror (x) is correctly given by (Graphs are drawn schematically and are not to scale) **[8 Jan, 2020 (Shift-II)]**



25. When an object is kept at a distance of 30 cm from a concave mirror, the image is formed at a distance of 10 cm from the mirror. If the object is moved with a speed of 9 cm s^{-1}, the speed (in cm s^{-1}) with which image moves at that instant is _____. **[3 Sep, 2020 (Shift-II)]**

26. A convex lens (of focal length 20 cm) and a concave mirror, having their principal axes along the same lines, are kept 80 cm apart from each other. The concave mirror is to the right of the convex lens. When an object is kept at a distance of 30 cm to the left of the convex lens, its image remains at the same position even if the concave mirror is removed. The maximum distance of the object for which this concave mirror, by itself would produce a virtual image would be: **[8 April, 2019 (Shift-II)]**

(a) 20 cm (b) 10 cm (c) 25 cm (d) 30 cm

27. A concave mirror for face viewing has focal length of 0.4 m. The distance at which you hold the mirror from your face in order to see your image upright with a magnification of 5 is: **[9 April, 2019 (Shift-I)]**

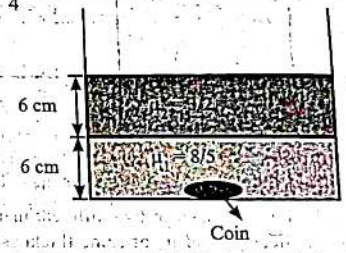
(a) 1.60 m (b) 0.24 m (c) 0.16 m (d) 0.32 m

28. Car B overtakes another car A at a relative speed of 40 ms^{-1}. How fast will the image of car B appear to move in the mirror of focal length 10 cm fitted in car A, when the car B is 1.9 m away from the car A ? **[26 Aug, 2021 (Shift-I)]**

(a) 0.1 ms^{-1} (b) 0.2 ms^{-1} (c) 4 ms^{-1} (d) 40 ms^{-1}

Refraction from Plane Surface

29. Two immiscible liquids of refractive indices $\frac{8}{5}$ and $\frac{3}{2}$ respectively are put in a beaker as shown in the figure. The height of each column is 6 cm. A coin is placed at the bottom of the beaker. For near normal vision, the apparent depth of the coin is $\frac{\alpha}{4}$ cm. The value of α is _____. **[27 Jan, 2024 (Shift-I)]**



30. A vessel of depth 'd' is half filled with oil of refractive index n_1 and the other half is filled with water of refractive index n_2. The apparent depth of this vessel when viewed from above will be **[13 Apr 2023 (Shift-I)]**

(a) $\frac{dn_1n_2}{(n_1+n_2)}$ (b) $\frac{d(n_1+n_2)}{2n_1n_2}$ (c) $\frac{dn_1n_2}{2(n_1+n_2)}$ (d) $\frac{2d(n_1+n_2)}{n_1n_2}$

31. A monochromatic light wave with wavelength λ_1 and frequency ν_1 in air enters another medium. If the angle of incidence and angle of refraction at the interface are 45° and 30° respectively, then the wavelength λ_2 and frequency ν_2 of the refracted wave are: **[06 Apr, 2023 (Shift-I)]**

(a) $\lambda_2 = \lambda_1, \nu_2 = \sqrt{2}\nu_1$ (b) $\lambda_2 = \frac{1}{\sqrt{2}}\lambda_1, \nu_2 = \nu_1$

(c) $\lambda_2 = \sqrt{2}\lambda_1, \nu_2 = \nu_1$ (d) $\lambda_2 = \lambda_1, \nu_2 = \frac{1}{\sqrt{2}}\nu_1$

@FAKE_JEE_X@TELEGRAM

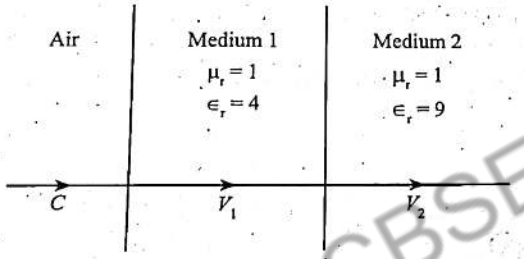
32. A ray of light is incident from air to a glass plate having thickness $\sqrt{3}$ cm and refractive index $\sqrt{2}$. The angle of incidence of the ray is equal to the critical angle for the glass-air interface. The lateral displacement of the ray when it passes through the plate is ____ $\times 10^{-2}$ cm (sin 15° = 0.26) **[25 Jan, 2023 (Shift-I)]**

33. A pole is vertically submerged in swimming pool, such that it gives a length of shadow 2.15 *m* within water when sunlight is incident at an angle of 30° with the surface of water. If swimming pool is filled to a height of 1.5 *m*, then the height of the pole above the water surface in centimeters is $(n_w = 4/3)$_____. **[6 Apr, 2023 (Shift-I)]**

34. A fish rising vertically upward with a uniform velocity of 8 ms^{-1}, observes that a bird is diving vertically downward towards the fish with the velocity of 12 ms^{-1}. If the refractive index of water is 4/3, then the actual velocity of the diving bird to pick the fish, will be _____ ms^{-1}. **[13 Apr, 2023 (Shift-I)]**

35. For an object placed at a distance 2.4 m from a lens, a sharp focused image is observed on a screen placed at a distance 12cm from the lens. A glass plate, of refractive index 1.5 and thickness 1cm is introduced between lens and screen such that the glass plate plane faces parallel to the screen. By what distance should the object be shifted so that a sharp focused image is observed again on the screen? **[25 July, 2022 (Shift-II)]**
(*a*) 0.8 m (*b*) 3.2 m (*c*) 1.2 m (*d*) 5.6 m

36. As shown in the figure, after passing through the medium 1. The speed of light v_2 in medium 2 will be:
(Given $c = 3 \times 10^8$ ms^{-1}) **[28 July, 2022 (Shift-I)]**



(*a*) 1.0×10^8 ms^{-1} (*b*) 0.5×10^8 ms^{-1}
(*c*) 1.5×10^8 ms^{-1} (*d*) 3.0×10^8 ms^{-1}

37. Time taken by light to travel in two different materials A and B refractive indices μ_A and μ_B of same thickness is t_1 and t_2 respectively. If $t_2 - t_1 = 5 \times 10^{-10}$ s and the ratio of μ_A and μ_B is 1 : 2. Then, the thickness of material, in meter is: (Given υ_A and υ_B are velocities of light in A and B materials respectively.) **[25 July, 2022 (Shift-I)]**
(*a*) $5 \times 10^{-10}\,\upsilon_A$ m (*b*) 5×10^{-10} m
(*c*) 1.5×10^{-10} m (*d*) $5 \times 10^{-10}\,\upsilon_B$ m

38. Consider a light ray travelling in air is incident into a medium of refractive index $\sqrt{2n}$. The incident angle is twice that of refracting angle. Then, the angle of incidence will be **[27 June, 2022 (Shift-I)]**
(*a*) $\sin^{-1}\left(\sqrt{n}\right)$ (*b*) $\cos^{-1}\left(\sqrt{\frac{n}{2}}\right)$
(*c*) $\sin^{-1}\left(\sqrt{2n}\right)$ (*d*) $2\cos^{-1}\left(\sqrt{\frac{n}{2}}\right)$

39. The difference of speed of light in the two media *A* and *B* ($v_A - v_B$) is 2.6×10^7 m/s. If the refractive index of medium *B* is 1.47, then the ratio of refractive index of medium *B* to medium *A* is: (Given: speed of light in vacuum $c = 3 \times 10^8$ ms^{-1}) **[25 June, 2022 (Shift-I)]**
(*a*) 1.303 (*b*) 1.318 (*c*) 1.13 (*d*) 0.12

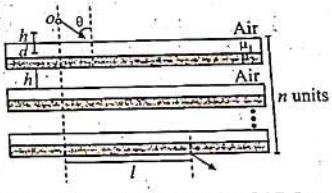
40. Light enters from air into a given medium at an angle of 45° with interface of the air-medium surface. After refraction, the light ray is deviated through an angle of 15° from its original direction. The refractive index of the medium is: **[29 July, 2022 (Shift-II)]**
(*a*) 1.732 (*b*) 1.333 (*c*) 1.414 (*d*) 2.732

41. A ray of light is incident at an angle of incidence 60° on the glass slab of refractive index $\sqrt{3}$. After refraction, the light ray emerges out from other parallel faces and lateral shift between incident ray and emergent ray is $4\sqrt{3}$cm. The thickness of the glass slab is _____ cm. **[24 June, 2022 (Shift-II)]**

42. A small bulb is placed at the bottom of a tank containing water to a depth of $\sqrt{7}$ m. The refractive index of water is $\frac{4}{3}$. The area of the surface of water through which light from the bulb can emerge out is $x\pi$ m^2. The value of *x* is _____. **[26 June, 2022 (Shift-II)]**

43. The $X-Y$ plane be taken as the boundary between two transparent media M_1 and M_2. M_1 in $z \geq 0$ has a refractive index of $\sqrt{2}$ and M_2 with $Z < 0$ has refractive index of $\sqrt{3}$. A ray of light travelling in M_1 along the direction given by the vector $\vec{P} = 4\sqrt{3}\hat{i} - 3\sqrt{3}\hat{j} - 5\hat{k}$, is incident on the plane of separation. The value of difference between the angle of incident in M_1 and the angle of refraction in M_2 will be _____ degree. **[29 July, 2022 (Shift-I)]**

44. Consider a configuration of *n* identical units, each consisting of three layers. The first layer is a column of air of height $h = \frac{1}{3}$ cm, and the second and third layers are of equal thickness $d = \frac{\sqrt{3}-1}{2}$ cm, and refractive indices $\mu_1 = \sqrt{\frac{3}{2}}$ and $\mu_2 = \sqrt{3}$, respectively. A light source *O* is placed on the top of the first unit, as shown in the figure. A ray of light from *O* is incident on the second layer of the first unit at an angle of $\theta = 60°$ to the normal. For a specific value of *n*, the ray of light emerges from the bottom of the configuration at a distance $l = \frac{8}{\sqrt{3}}$ cm, as shown in the figure. The value of *n* is _____. **[JEE Advance 2022]**



45. A glass tumbler having inner depth of 17.5 cm is kept on a table. A student starts pouring water ($\mu = 4/3$) into it while looking at the surface of water from the above. When he feels that the tumbler is half filled, he stops pouring water. Up to what height, the tumbler is actually filled? **[1 Sept, 2021 (Shift-II)]**
(*a*) 11.7 cm (*b*) 8.75 cm (*c*) 7.5 cm (*d*) 10 cm

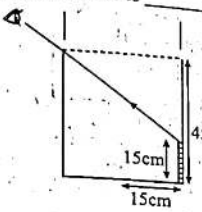
46. A ray of laser of a wavelength 630 nm is incident at an angle of 30° at the diamond- air interface. It is going from diamond to air. The refractive index diamond is 2.42 and that of air is 1. Choose the correct option. **[25 July, 2021 (Shift-I)]**
(*a*) Angle of refraction is 53.4° (*b*) Angle of refraction is 30°
(*c*) Angle of refraction is 24.41° (*d*) Refraction is not possible

@FREE CBSE X @RATED BOOKLET

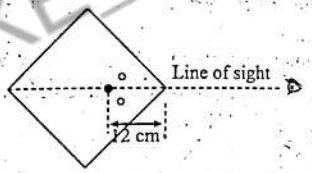
47. There is a small source of light at some depth below the surface of water (refractive index = 4/3) in a tank of large cross sectional surface area. Neglecting any reflection from the bottom and absorption by water, percentage of light that emerges out of surface is (nearly): [Use the fact that surface area of spherical cap of height h and radius of curvature r is $2\pi rh$] [9 Jan, 2020 (Shift-II)]
(a) 21% (b) 17% (c) 50% (d) 34%

48. A vessel of depth $2h$ is half filled with a liquid of refractive index $2\sqrt{2}$ and the upper half with another liquid of refractive index $\sqrt{2}$. The liquids are immiscible. The apparent depth of the inner surface of the bottom of vessel will be [9 Jan, 2020 (Shift-I)]
(a) $\frac{h}{\sqrt{2}}$ (b) $\frac{h}{2(\sqrt{2}+1)}$ (c) $\frac{3}{4}h\sqrt{2}$ (d) $\frac{h}{3\sqrt{2}}$

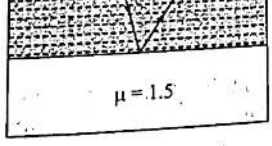
49. An observer can see through a small hole on the side of a jar (radius 15 cm) at a point at height of 15 cm from the bottom (see figure). The hole is at a height of 45 cm. When the jar is filled with a liquid upto a height of 30 cm the same observer can see the edge at the bottom of the jar. If the refractive index of the liquid is $N/100$, where N is an integer, the value of N is _____. [3 Sep, 2020 (Shift-I)]



50. A large square container with thin transparent vertical walls and filled with water (refractive index $\frac{4}{3}$) is kept on a horizontal table. A student holds a thin straight wire vertically inside the water 12 cm from one of its corners, as shown schematically in the figure. Looking at the wire from this corner, another student sees two images of the wire, located symmetrically on each side of the line of sight as shown. The separation (in cm) between these images is [JEE Advance 2020]

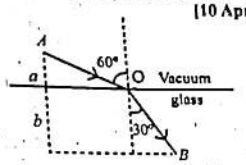


51. Consider a tank made of glass (refractive index 1.5) with a thick bottom. It is filled with a liquid of refractive index μ. A student finds that, irrespective of what the incident angle i (see figure) is for a beam of light entering the liquid, the light reflected from the liquid glass interface is never completely polarized. For this to happen, the minimum value of μ is [9 Jan, 2019 (Shift-I)]



(a) $\sqrt{\frac{5}{3}}$ (b) $\frac{3}{\sqrt{5}}$ (c) $\frac{5}{\sqrt{3}}$ (d) $\frac{4}{3}$

52. A ray of light AO in vacuum is incident on a glass slab at angle 60° and refracted at angle 30° along OB as shown in the figure. The optical path length of light ray from A to B is: [10 April, 2019 (Shift-I)]



(a) $2a+\frac{2b}{\sqrt{3}}$ (b) $2a+\frac{2b}{3}$ (c) $\frac{2\sqrt{3}}{a}+2b$ (d) $2a+2b$

Total Internal Reflection and Critical Angle

53. A light ray is incident on a glass slab of thickness $4\sqrt{3}$ cm and refractive index $\sqrt{2}$. The angle of incidence is equal to the critical angle for the glass slab with air. The lateral displacement of ray after passing through glass slab is _____cm. [04 April, 2024 (Shift-II)]
(Given sin 15° = 0.25)

54. Critical angle of incidence for a pair of optical media is 45°. The refractive indices of first and second media are in the ratio: [08 April, 2024 (Shift-I)]
(a) $\sqrt{2}:1$ (b) 1 : 2 (c) $1:\sqrt{2}$ (d) 2 : 1

55. The critical angle for a denser-rarer interface is 45°. The speed of light in rarer medium is 3×10^8 m/s. The speed of light in the denser medium is: [11 Apr 2023 (Shift-I)]
(a) 7.5×10^7 m/s (b) 2.12×10^8 m/s
(c) 3.12×10^7 m/s (d) $\sqrt{2}\times10^8$ m/s

56. In a medium the speed of light wave decreases to 0.2 times to its speed in free space The ratio of relative permittivity to the refractive index of the medium is x:1. The value of x is _____.
(Given speed of light in free space = 3×10^8 ms^{-1} and for the given medium $\mu_r = 1$) [31 Jan 2023 (Shift-I)]

57. The speed of light in media 'A' and 'B' are 2.0×10^{10} cm/s and 1.5×10^{10} cm/s respectively. A ray of light enters from the medium B to A an incident angle 'θ'. If the ray suffers total internal reflection, then [29 June, 2022 (Shift-II)]
(a) $\theta=\sin^{-1}\left(\frac{3}{4}\right)$ (b) $\theta>\sin^{-1}\left(\frac{2}{3}\right)$
(c) $\theta<\sin^{-1}\left(\frac{3}{4}\right)$ (d) $\theta>\sin^{-1}\left(\frac{3}{4}\right)$

58. Light travels in two media M_1 and M_2 with speeds 1.5×10^8 ms^{-1} and 2.0×10^8 ms^{-1} respectively. The critical angle between them is: [26 July, 2022 (Shift-II)]
(a) $\tan^{-1}\left(\frac{3}{\sqrt{7}}\right)$ (b) $\tan^{-1}\left(\frac{2}{3}\right)$
(c) $\cos^{-1}\left(\frac{3}{4}\right)$ (b) $\sin^{-1}\left(\frac{2}{3}\right)$

@FAKE_SORRY@NEETJUNET

59. A light wave travelling linearly in a medium of dielectric constant 4, incident on the horizontal interface separating medium with air. The angle of incidence for which the total intensity of incident wave will be reflected back into the same medium will be (Given: relative permeability of medium $\mu = 1$) **[25 June, 2022 (Shift-I)]**

(a) 10° (b) 20° (c) 30° (d) 60°

60. Which of the following statement is correct? **[25 July, 2022 (Shift-I)]**

(a) In primary rainbow, observer sees red colour on the top and violet on the bottom

(b) In primary rainbow, observer sees violet colour on the top and red on the bottom

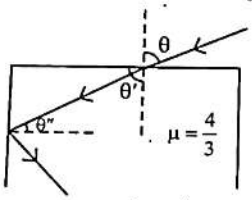
(c) In primary rainbow, light wave suffers total internal reflection twice before coming out of water drops.

(d) Primary rainbow is less bright than secondary rainbow.

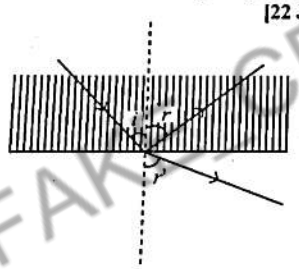
61. A ray of light entering from air into a denser medium of refractive index $\frac{4}{3}$, as shown in figure. The light ray suffers total internal reflection at the adjacent surface as shown. The maximum value of angle θ should be equal to: **[25 July, 2021 (Shift-II)]**

(a) $\sin^{-1}\frac{\sqrt{5}}{4}$ (b) $\sin^{-1}\frac{\sqrt{7}}{3}$

(c) $\sin^{-1}\frac{\sqrt{7}}{4}$ (d) $\sin^{-1}\frac{\sqrt{5}}{3}$



62. A ray of light passes from a denser medium to a rarer medium at an angle of incidence i. The reflected and refracted rays make an angle of 90° with each other. The angle of reflection and refraction are respectively r and r'. The critical angle is given by: **[22 July, 2021 (Shift-II)]**



(a) $\sin^{-1}(\cot r)$ (b) $\tan^{-1}(\sin i)$

(c) $\sin^{-1}(\tan r')$ (d) $\sin^{-1}(\tan r)$

63. Red light differs from blue light as they have **[16 March, 2021 (Shift-II)]**

(a) Different frequencies and different wavelengths

(b) Different frequencies and same wavelengths

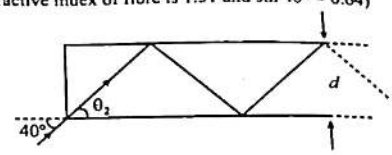
(c) Same frequencies and same wavelengths

(d) Same frequencies and different wavelengths

64. The critical angle of a medium for a specific wavelength, if the medium has relative permittivity 3 and relative permeability $\frac{4}{3}$ for this wavelength, will be: **[8 Jan, 2020 (Shift-I)]**

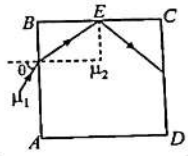
(a) 15° (b) 30° (c) 60° (d) 45°

65. In figure, the optical fiber is $l = 2$ m long and has a diameter of $d = 20$ μm. If a ray of light is incident on one end of the fiber at angle $\theta_1 = 40°$, the number of reflection it makes before emerging from the other end is close to: **[8 April, 2019 (Shift-I)]**
(refractive index of fibre is 1.31 and sin 40° = 0.64)



(a) 55000 (b) 57000 (c) 66000 (d) 45000

66. A transparent cube of side d, made of a material of refractive index μ_2, is immersed in a liquid of refractive index $\mu_1(\mu_1 < \mu_2)$. A ray is incident on the face AB at an angle θ (shown in the figure). Total internal reflection takes place at point E on the face BC. **[12 April, 2019 (Shift-II)]**



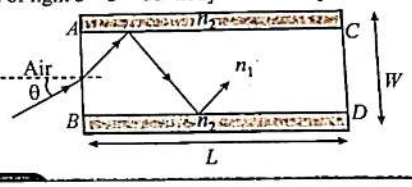
The θ must satisfy:

(a) $\theta < \sin^{-1}\frac{\mu_1}{\mu_2}$ (b) $\theta < \sin^{-1}\sqrt{\frac{\mu_2^2}{\mu_1^2}-1}$

(c) $\theta > \sin^{-1}\frac{\mu_1}{\mu_2}$ (d) $\theta > \sin^{-1}\sqrt{\frac{\mu_2^2}{\mu_1^2}-1}$

67. A planar structure of length L and width W is made of two different optical media of refractive indices $n_1 = 1.5$ and $n_2 = 1.44$ as shown in figure. If $L >> W$, a ray entering from end AB will emerge from end CD only if the total internal reflection condition is met inside the structure. For $L = 9.6$ m, if the incident angle θ is varied, the maximum time taken by a ray to exit the plane CD is $t \times 10^{-9}$ s, where t is ____.

[Speed of light $c = 3 \times 10^8$ m/s] **[JEE Advanced 2019]**



Prism

68. The refractive index of a prism with apex angle A is cot A/2. The angle of minimum deviation is: **[31 Jan, 2024 (Shift-I)]**

(a) $\delta_m = 180° - A$ (b) $\delta_m = 180° - 3A$

(c) $\delta_m = 180° - 4A$ (d) $\delta_m = 180° - 2A$

69. If the refractive index of the material of a prism is $\cot\left(\frac{A}{2}\right)$ where A is the angle of prism then the angle of minimum deviation will be **[27 Jan, 2024 (Shift-I)]**

(a) $\pi - 2A$ (b) $\frac{\pi}{2} - 2A$ (c) $\pi - A$ (d) $\frac{\pi}{2} - A$

@FAKE_CBSE_RAJ_EDUNET

Given below are two statements :
Statement I: When the white light passed through a prism, the red light bends lesser than yellow and violet.
Statement II: The refractive indices are different for different wavelengths in dispersive medium. In the light of the above statements, choose the correct answer from the options given below:
[05 April, 2024 (Shift-II)]

(a) Both Statement I and Statement II are true.
(b) Statement I is true but Statement II is false.
(c) Both Statement I and Statement II are false.
(d) Statement I is false but Statement II is true.

71. The refractive index of prism is $\mu = \sqrt{3}$ and the ratio of the angle of minimum deviation to the angle of prism is one. The value of angle of prism is _____°.

72. A thin prism P_1 with an angle 6° and made of glass of refractive index 1.54 is combined with another prism P_2 made from glass of refractive index 1.72 to produce dispersion without average deviation. The angle of prism P_2 is: **[30 Jan, 2023 (Shift-II)]**
(a) 6° (b) 1.3° (c) 7.8° (d) 4.5°

73. The refractive index of a transparent liquid filled in an equilateral hollow prism is $\sqrt{2}$. The angle of minimum deviation for the liquid will be_____. **[15 Apr, 2023 (Shift-I)]**

74. A plane polarized blue light ray is incident on a prism such that there is no reflection from the surface of the prism. The angle of deviation of the emergent ray is $\delta = 60°$ Fig. 1. The angle of minimum deviation for red light from the same prism is $\delta_{min} = 30°$ Fig. 2. The refractive index of the prism material for blue light is $\sqrt{3}$. Which of the following statements is are correct?
[JEE Advanced 2023]

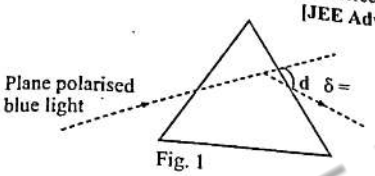


Fig. 1

Fig. 1.

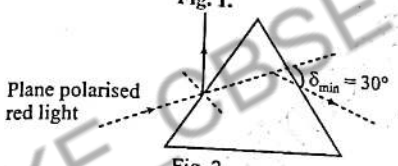


Fig. 2

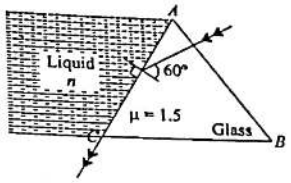
Fig. 2.

(a) The blue light is polarized in the plane of incidence.
(b) The angle of the prism is 45°.
(c) The refractive index of the material of the prism for red light is $\sqrt{2}$.
(d) The angle of refraction for blue light in air at the exit plane of the prism is 60°.

75. The refracting angle of a prism is A and refractive index of the material of the prism is cot $(A/2)$. Then the angle of minimum deviation will be: **[28 June, 2022 (Shift-I)]**
(a) $180 - 2A$ (b) $90 - A$ (c) $180 + 2A$ (d) $180 - 3A$

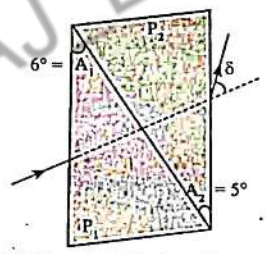
76. A light whose electric field vectors are completely removed by using a good Polaroid, allowed to incident on the surface of the prism at Brewster's angle. Choose the most suitable option for the phenomenon related to the prism. **[25 June, 2022 (Shift-II)]**
(a) Reflected and refracted rays will be perpendicular to each other.
(b) Wave will propagate along the surface of prism.
(c) No refraction, and there will be total reflection of light.
(d) No reflection, and there will be total transmission of light.

77. In the given figure, the face AC of the equilateral prism is immersed in a liquid of refractive index 'n'. For incident angle 60° at the side AC, the refracted light beam just grazes along face AC. The refractive index of the liquid $n = \frac{\sqrt{x}}{4}$.



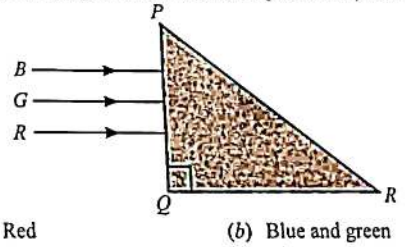
The value of x is _____.
(Given refractive index of glass = 1.5) **[26 July, 2022 (Shift-II)]**

78. A thin prism of angle 6° and refractive index for yellow light (n_y) 1.5 is combined with another prism of angle 5° and $n_y = 1.55$. The combination produces no dispersion. The net average deviation (δ) produced by the combination is $\left(\frac{1}{x}\right)^0$. The value of x is _____.
[27 July, 2022 (Shift-II)]



79. A deviation of 2° is produced in the yellow ray when prism of crown and flint glass are achromatically combined. Taking dispersive powers of crown and flint glass as 0.02 and 0.03 respectively and refractive index for yellow light for these glasses are 1.5 and 1.6 respectively. The refracting angles for crown glass will be _____°. (in degree) Round off to the Nearest Integer)
[16 March, 2021 (Shift-II)]

80. Three rays of light, red (R), green (G) and blue (B) are incident on the face PQ of a right angled prism PQR as shown in the figure. The refractive indices of material of the prism for red, green and blue wavelength are 1.27, 1.42 and 1.49 respectively. The colour of ray(s) emerging out of the face PR is **[18 March, 2021 (Shift-II)]**



(a) Red (b) Blue and green
(c) Green (d) Blue

@FAKE_CBSE_X @RAJ_EDIT

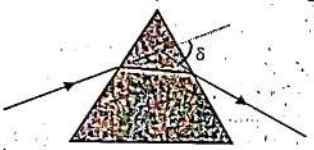
81. A prism of refractive index μ and angle of prism A is placed in the position of minimum angle of deviation. If minimum angle of deviation is also A, then in terms of refractive index value of A is:
[25 July, 2021 (Shift-II)]

(a) $2\cos^{-1}\left(\frac{\mu}{2}\right)$ (b) $\cos^{-1}\left(\frac{\mu}{2}\right)$

(c) $\sin^{-1}\left(\frac{\mu}{2}\right)$ (d) $\sin^{-1}\left(\sqrt{\frac{\mu-1}{2}}\right)$

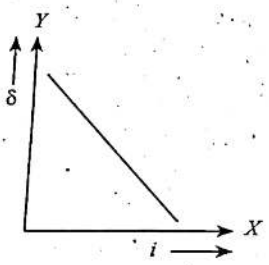
82. The angle of deviation through a prism is minimum when
[16 March, 2021 (Shift-I)]

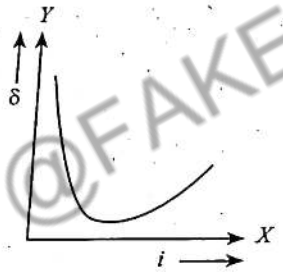
A. Incident ray and emergent ray are symmetric to the prism
B. The refracted ray inside the prism becomes parallel to its base
C. Angle if incidence is equal to that of the angle of emergence
D. When angle of emergence is double the angle of incidence

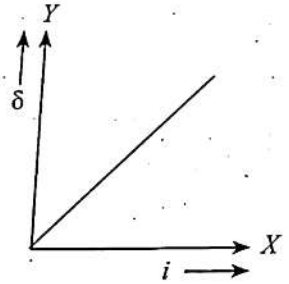


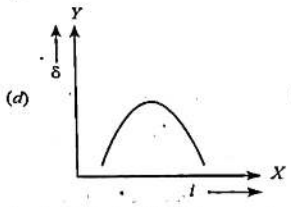
Choose the correct answer from the options given below :
(a) Statements (B) and (C) are true
(b) Statements (A), (B) and (C) are true
(c) Only statement (D) is true
(d) Only statements (A) and (B) are true

83. The expected graphical representation of the variation of angle of deviation 'δ' with angle of incidence 'i' in a prism is :
[27 July, 2021 (Shift-II)]

(a)


(b)


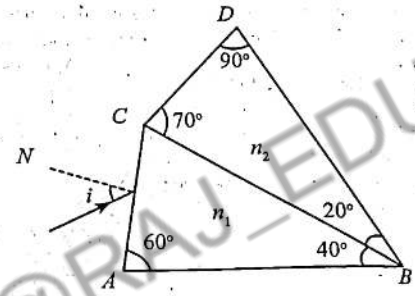
(c)


(d)


84. A prism of refractive index n_1 and another prism of refractive index n_2 are stuck together (as shown in the figure). n_1 and n_2 depend on λ, the wavelength of light, according to the relation

$$n_1 = 1.2 + \frac{10.8\times10^{-14}}{\lambda^2} \text{ and } n_2 = 1.45 + \frac{1.8\times10^{-14}}{\lambda^2}.$$

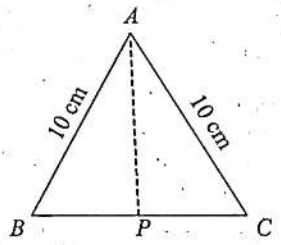
The wavelength for which rays incident at any angle on the interface BC pass through without bending at that interface will be _____ nm. **[27 July, 2021 (Shift-I)]**



85. A ray of light passing through a prism ($\mu = \sqrt{3}$) surface minimum deviation. It is found that the angle of incidence is double the angle of refraction within the prism. Then, the angle of prism is _____(in degrees). **[22 July, 2021 (Shift-II)]**

86. Cross–section view of a prism is the equilateral triangle ABC in the figure. The minimum deviation is observed using this prism when the angle of incidence is equal to the prism angle. The time taken by light to travel from P (midpoint of BC) to A is _____ $\times 10^{-10}$ s.

(Given, speed of light in vacuum = 3×10^8 m/s and $\cos30^\circ = \frac{\sqrt{3}}{2}$)

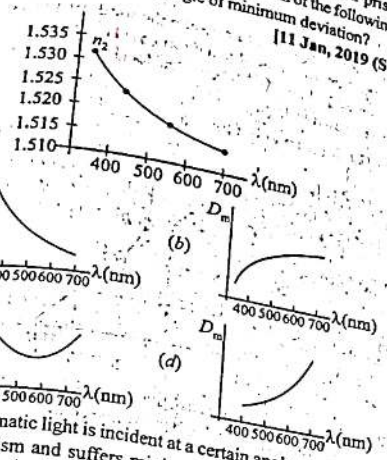


[22 July, 2021 (Shift-II)]

87. A prism of angle $A = 1^\circ$ has a refractive index $\mu = 1.5$. A good estimate for the minimum angle of deviation (in degrees) is close to $\frac{N}{10}$. The value of N is ____. **[5 Sep, 2020 (Shift-II)]**

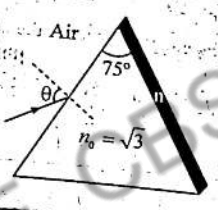
@FAKE_CBSE_X_@RAJ_EDUNET

88. The variation of refractive index of a crown glass thin prism with wavelength of the incident light is shown. Which of the following graph is the correct one, if D_m is the angle of minimum deviation?
[11 Jan, 2019 (Shift-I)]



89. A monochromatic light is incident at a certain angle on an equilateral triangular prism and suffers minimum deviation. If the refractive index of the material of the prism is $\sqrt{3}$, then the angle of incidence
(a) 90° (b) 30° (c) 60° (d) 45°
[11 Jan, 2019 (Shift-II)]

90. A monochromatic light is incident from air on a refracting surface of a prism of angle 75° and refractive index $n_0 = \sqrt{3}$. The other refracting surface of a prism is coated by a thin film of material of refractive index n as shown in figure. The light suffers total internal reflection at the coated prism surface for an incidence angle of $\theta \le 60°$.
The value of n^2 is_____.
[JEE Advance 2019]

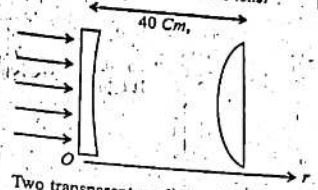


Refraction at Curved Surface

91. Light from a point source in air falls on a convex curved surface of radius 20 cm and refractive index 1.5. If the source is located at 100 cm from the convex surface, the image will be formed at____ cm from the object.
[31 Jan, 2024 (Shift-II)]

92. An ice cube has a bubble inside. When viewed from one side the apparent distance of the bubble is 12 cm. when viewed from the opposite side, the apparent distance of the bubble is observed as 4 cm. If the side of the ice cube is 24 cm, the refractive index of the ice cube is
[12 Apr, 2023 (Shift-I)]
(a) $\frac{4}{3}$ (b) $\frac{3}{2}$ (c) $\frac{2}{3}$ (d) $\frac{6}{5}$

93. As shown in the figure, a combination of a thin plano concave lens and a thin plano convex lens is used to image an object placed at infinity. The radius of curvature of both the lenses is 30 *cm* and refractive index of the material for both the lenses is 1.75. Both the lenses are placed at distance of 40 *cm* from each other. Due to the combination, the image of the object is formed at distance $x =$ _____ *cm*, from concave lens.
[24 Jan, 2023 (Shift-I)]

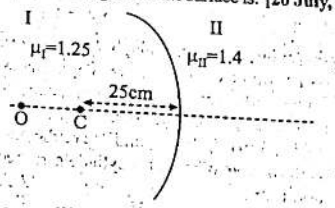


94. Two transparent media having refractive indices 1.0 and 1.5 are separated by a spherical refracting surface of radius of curvature 30 cm. The centre of curvature of surface is towards denser medium and a point object is placed on the principle axis in rarer medium at a distance of 15 cm from the pole of the surface. The distance of image from the pole of the surface is _____ cm.
[8 Apr, 2023 (Shift-II)]

95. A parallel beam of light is allowed to fall on a transparent spherical globe of diameter 30 cm and refractive index 1.5. The distance from the centre of the globe at which the beam of light can converge is _____ mm.
[29 June, 2022 (Shift-I)]

96. A convex lens of focal length 20 cm is placed in front of a convex mirror with principal axis coinciding each other. The distance between the lens and mirror is 10 cm. A point object is placed on principal axis at a distance of 60 cm from the convex lens. The image formed by combination coincides the object itself. The focal length of the convex mirror is _____cm.
[25 July, 2022 (Shift-II)]

97. Region I and II are separated by a spherical surface of radius 25 cm. An object is kept in region I at a distance of 40 cm from the surface. The distance of the image from the surface is: [20 July, 2021 (Shift-I)]



(a) 9.52 cm (b) 18.23 cm (c) 37.58 cm (d) 55.44 cm

98. The image of an object placed in air formed by a convex refracting surface is at a distance of 10 behind the surface. The image is real and is at $\frac{2}{3}$rd of the distance of the object from the surface. The wavelength of light inside the surface is $\frac{2}{3}$ times the wavelength in air. The radius of the curved surface is $\frac{x}{13}$ m. The value of x is _____.
[17 March, 2021 (Shift-II)]

99. A light ray enters a solid glass sphere of refractive index $\mu = \sqrt{3}$ at an angle of incidence 60°. The ray is both reflected and refracted at the farther surface of the sphere. The angle (in degrees) between the reflected and refracted rays at this surface is _____.
[2 Sep, 2020 (Shift-II)]

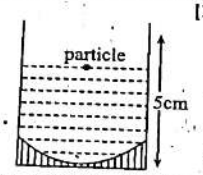
@JEE_ADVANCE_KA_CHASE

100. The eye can be regarded as a single refracting surface. The radius of curvature of this surface is equal to that of cornea (7.8 mm). This surface separates two media of refractive indices 1 and 1.34. Calculate the distance from the refracting surface at which a parallel beam of light will come to focus. **[10 Jan, 2019 (Shift-II)]**

(*a*) 1 cm (*b*) 2 cm (*c*) 4.0 cm (*d*) 3.1 cm

101. A concave mirror has radius of curvature of 40 cm. It is at the bottom of a glass that has water filled up to 5 cm (see figure). If a small particle is floating on the surface of water, its image as seen, from directly above the glass, is at a distance *d* from the surface of water. The value of *d* is close to: (Refractive index of water = 1.33)

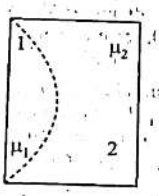
[12 April, 2019 (Shift-I)]



(*a*) 8.8 cm (*b*) 11.7 cm (*c*) 6.7 mm (*d*) 13.4 cm

102. One plano-convex and one plano-concave lens of same radius of curvature 'R' but of different materials are joined side by side as shown in the figure. If the refractive index of the material of 1 is μ_1 and that of 2 is μ_2, then the focal length of the combination is:

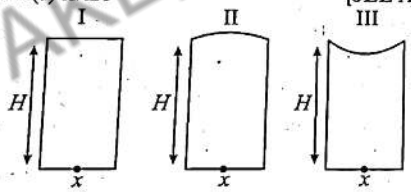
[10 April, 2019 (Shift-I)]



(*a*) $\frac{R}{2-(\mu_1-\mu_2)}$ (*b*) $\frac{2R}{\mu_1-\mu_2}$

(*c*) $\frac{R}{2(\mu_1-\mu_2)}$ (*d*) $\frac{R}{\mu_1-\mu_2}$

103. Three glass cylinders of equal height $H = 30$ cm and same refractive index $n = 1.5$ are placed on a horizontal surfaces shown in figure. Cylinder I has a flat top, cylinder II has a convex top and cylinder III has a concave top. The radii of curvature of the two curved tops are same ($R = 3$ m). If H_1, H_2 and H_3 are the apparent depths of a point X on the bottom of the three cylinders, respectively, the correct statement(s) is/are **[JEE Advance 2019]**



(*a*) $H_3 > H_1$ (*b*) $0.8\text{ cm} < (H_2 - H_1) < 0.9\text{ cm}$

(*c*) $H_2 > H_3$ (*d*) $H_2 > H_1$

Lens

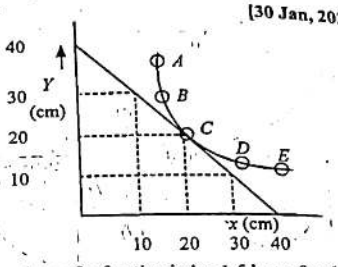
104. The distance between object and its 3 times magnified virtual image as produced by a convex lens is 20 cm. The focal length of the lens used is _____ cm. **[1 Feb, 2024 (Shift-I)]**

105. The distance between object and its two times magnified real image as produced by a convex lens is 45 cm. The focal length of the lens used is _____ cm. **[30 Jan, 2024 (Shift-I)]**

106. In an experiment to measure the focal length (f) of a convex lens, the magnitude of object distance (x) and the image distance (y) are measured with reference to the focal point of the lens. The $y-x$ plot is shown in figure.

The focal length of the lens is _____ cm.

[30 Jan, 2024 (Shift-II)]



107. A biconvex lens of refractive index 1.5 has a focal length of 20 cm in air. Its focal length when immersed in a liquid of refractive index 1.6 will be: **[29 Jan, 2024 (Shift-I)]**

(*a*) −16 cm (*b*) −160 cm (*c*) +160 cm (*d*) +16 cm

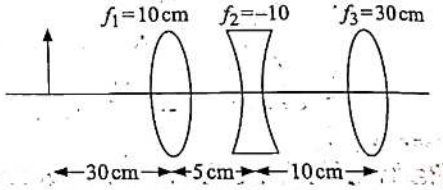
108. An effective power of a combination of 5 identical convex lenses which are kept in contact along the principal axis is 25 D. Focal length of each of the convex lens is: **[04 April, 2024 (Shift-I)]**

(*a*) 20 cm (*b*) 50 cm (*c*) 500 cm (*d*) 25 cm

109. For the thin convex lens, the radii of curvature are at 15 cm and 30 cm respectively. The focal length the lens is 20 cm. The refractive index of the material is: **[06 April, 2024 (Shift-II)]**

(*a*) 1.2 (*b*) 1.4 (*c*) 1.5 (*d*) 1.8

110. The position of the image formed by the combination of lenses is: **[08 April, 2024 (Shift-II)]**



(*a*) 30 cm (right of third lens) (*b*) 15 cm (left of second lens)

(*c*) 30 cm (left of third lens) (*d*) 15 cm (right of second lens)

111. Given below are two statements:

Statement (I): When an object is placed at the centre of curvature of a concave lens, image is formed at the centre of curvature of the lens on the other side.

Statement (II): Concave lens always forms a virtual and erect image.

In the light of the above statements, choose the correct answer from the options given below: **[09 April, 2024 (Shift-I)]**

(*a*) Statement I is false but Statement II is true.

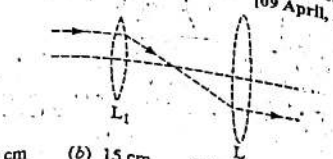
(*b*) Both Statement I and Statement II are false.

(*c*) Statement I is true but Statement II is false.

(*d*) Both Statement I and Statement II are true.

@FAKE_JEE_X @FAKE_EDUCET

having focal length 10 cm and 15 cm respectively. The distance between L_1 and L_2 is: [09 April, 2024 (Shift-II)]



(a) 10 cm (b) 15 cm (c) 25 cm (d) 35 cm

113. A person has been using spectacles of power –1.0 diopter for distant vision and a separate reading glass of power 2.0 diopters. What is the least distance of distinct vision for this person: [30 Jan, 2023 (Shift-I)]

(a) 10 cm (b) 40 cm (c) 30 cm (d) 50 cm

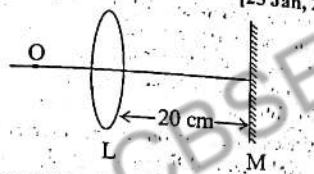
114. When a beam of white light is allowed to pass through convex lens parallel to principal axis, the different colours of light converge at different point on the principle axis after refraction. This is called: [24 Jan, 2023 (Shift-II)]

(a) Scattering (b) Chromatic aberration
(c) Spherical aberration (d) Polarisation

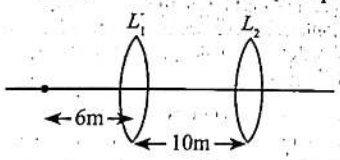
115. A bi convex lens of focal length 10 cm is cut in two identical parts along a plane perpendicular to the principal axis. The power of each lens after cut is ___ D. [13 Apr, 2023 (Shift-I)]

116. The radius of curvature of each surface of a convex lens having refractive index 1.8 is 20 cm. The lens is now immersed in a liquid of refractive index 1.5. The ratio of power of lens in air to its power in the liquid will be $x : 1$. The value of x is _____. [11 Apr, 2023 (Shift-I)]

117. An object is placed on the principal axis of convex lens of focal length 10 cm as shown. A plane mirror is placed on the other side of the lens at a distance of 20 cm. The image produced by the plane mirror is 5 cm inside the mirror. The distance of the object from the lens is _____ cm. [25 Jan, 2023 (Shift-II)]



118. A point object, 'O' is placed in front of two thin symmetrical coaxial convex lenses L_1 and L_2 with focal length 24 cm and 9 cm respectively. The distance between two lenses is 10 cm and the object is placed 6 cm away from lens L_1 as shown in the figure. The distance between the object and the image formed by the system of two lenses is _____cm. [10 Apr, 2023 (Shift-II)]

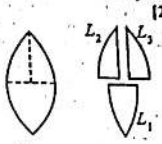


119. Two convex lenses of focal length 20 cm each are placed coaxially with a separation of 60 cm between them. The image of the distant object formed by the combination is at _____ cm from the first lens. [12 Apr, 2023 (Shift-I)]

120. A convex lens of refractive index 1.5 and focal length 18 cm in air is immersed in water. The change in focal length of the lens will be ____ cm. (Given refractive index of water $= \frac{4}{3}$) [24 Jan, 2023 (Shift-II)]

121. In an experiment for determination of the focal length of a thin convex lens, the distance of the object from the lens is 10 ± 0.1 cm and the distance of its real image from the lens is 20 ± 0.2 cm. The error in the determination of focal length of the lens is n%. The value of n is _____ : [JEE Adv, 2023]

122. A convex lens has power P. It is cut into two halves along its principal axis. Further one piece (out of the two halves) is cut into two halves perpendicular to the principal axis (as shown in figures). Choose the incorrect option for the reported pieces. [27 June, 2022 (Shift-II)]



(a) Power of $L_1 = \frac{P}{2}$ (b) Power of $L_2 = \frac{P}{2}$

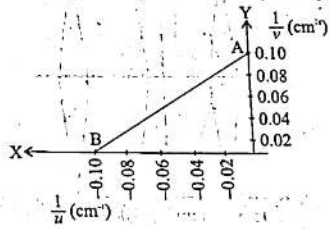
(c) Power of $L_3 = \frac{P}{2}$ (d) Power of $L_1 = P$

123. The power of lens (biconvex) is 1.25 m^{-1} in particular medium. Refractive index of the lens is 1.5 and radii of curvature are 20 cm and 40 cm respectively. The refractive index of surrounding medium: [28 July, 2022 (Shift-II)]

(a) 1.0 (b) $\frac{9}{7}$ (c) $\frac{3}{2}$ (d) $\frac{4}{3}$

124. Two identical thin biconvex lenses of focal length 15 cm and refractive index 1.5 are in contact with each other. The space between the lenses is filled with a liquid of refractive index 1.25. The focal length of the combination is _____cm. [24 June, 2022 (Shift-I)]

125. The graph between $\frac{1}{u}$ and $\frac{1}{v}$ for a thin convex lens in order to determine its focal length is plotted as shown in the figure. The refractive index of lens is 1.5 and its both the surfaces have same radius of curvature R. The value of R will be _____cm. (where u = object distance, v = image distance) [26 July, 2022 (Shift-I)]



126. In an experiment with a convex lens, The plot of the image distance (v') against the object distance (μ') measured from the focus gives a curve v'μ' = 225.If all the distances are measured in cm. The magnitude of the focal length of the lens is _____cm. [28 July, 2022 (Shift-II)]

127. The thickness at the centre of a plano- convex lens is 3mm and the diameter is 6cm. If the speed of light in the material of the lens is 2×10^8 ms^{-1}. The focal length of the lens is [17 March, 2021 (Shift-I)]

(a) 15 cm (b) 0.30 cm (c) 30 cm (d) 1.5 cm

@FREE CBSE X @ WHATSAPP

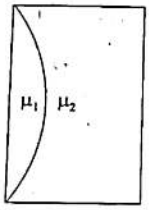
128. Your friend is having eye sight problem. She is not able to see clearly a distant uniform window mesh and it appears to her non-uniform and distorted. The doctor diagnosed the problems as: **[18 March, 2021 (Shift-I)]**

(a) Myopia with Astigmatism (b) Myopia and hypermetropia
(c) Astigmatism (d) Presbyopia with Astigmatism

129. The refractive index of converging lens is 1.4. What will be the focal length of this if it is placed in a medium of same refractive index? Assume the radii of curvature of the faces of lens are R_1 and R_2 respectively. **[16 March, 2021 (Shift-II)]**

(a) 1 (b) $\frac{R_1R_2}{R_1-R_2}$ (c) Infinite (d) Zero

130. Curved surfaces of a plano-convex lens of refractive index μ_1 and a planoconcave lens of refractive index μ_2 have equal radius of curvature as shown in figure. Find the ratio of radius of curvature to the focal length of the combined lenses. **[27 Aug, 2021 (Shift-II)]**



(a) $\frac{1}{\mu_2-\mu_1}$ (b) $\mu_2-\mu_1$ (c) $\frac{1}{\mu_1-\mu_2}$ (d) $\mu_1-\mu_2$

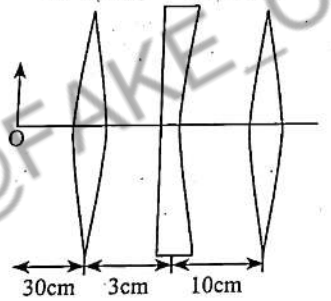
131. An object is placed at the focus of concave lens having focal length f. What is the magnification and distance of the image from the optical centre of the lens? **[31 Aug, 2021 (Shift-I)]**

(a) Very high, ∞ (b) $\frac{1}{4}, \frac{f}{4}$

(c) $\frac{1}{2}, \frac{f}{2}$ (d) $1, \infty$

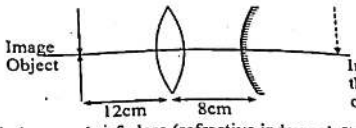
132. Find the distance of the image from object O, formed by the combination of lenses in the figure: **[27 Aug, 2021 (Shift-I)]**

(a) 75 cm (b) 20 cm (c) 10 cm (d) infinity



133. The same size images are formed by a convex lens by a convex lens when the object is placed at 20 cm or at 10 cm from the lens. The focal length of convex lens is ..... cm. **[25 Feb, 2021 (Shift-I)]**

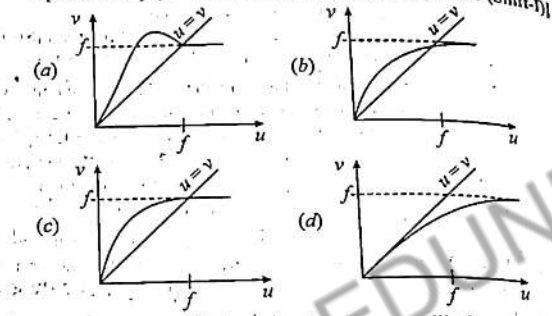
134. An object is placed at a distance of 12 cm from a convex lens. A convex mirror of focal length 15 cm is placed on other side of lens at 8 cm as shown in the figure. Image of object coincides with the object. When the convex mirror is removed, a real and inverted image is formed at a position. The distance of the image from the object will be _____ (cm). **[26 Aug, 2021 (Shift-II)]**



135. A thin lens made of glass (refractive index = 1.5) of focal length f = 16 cm is immersed in a liquid of refractive index 1.42. If its focal length in liquid is f_l, then the ratio f_l/f, if is closest to the integer: **[7 Jan, 2020 (Shift-II)]**

(a) 17 (b) 1 (c) 9 (d) 5

136. For a concave lens of focal length f, the relation between object and image distances u and v, respectively, from its pole can best be represented by ($u = v$ is the reference line) **[5 Sep, 2020 (Shift-I)]**



137. A double convex lens has power P and same radii of curvature R of both the surfaces. The radius of curvature of a surface of a plano-convex lens made of the same material with power 1.5 P is **[6 Sep, 2020 (Shift-II)]**

(a) $2R$ (b) $\frac{R}{2}$ (c) $\frac{3R}{2}$ (d) $\frac{R}{3}$

138. A point like object is placed at a distance of 1 m in front of convex lens of focal length 0.5 m. A plane mirror is placed at a distance of 2 m behind the lens. The position and nature of the final image formed by the system is: **[06 Sep, 2020 (Shift-I)]**

(a) 2.6 m from the mirror, real
(b) 1 m from the mirror, virtual
(c) 1 m from the mirror, real
(d) 2.6 m from the mirror, virtual

139. The distance between an object and a screen is 100 cm. A lens can produce real image of the object on the screen for two different positions between the screen and the object. The distance between these two positions is 40 cm. If the power of the lens is close to $\left(\frac{N}{100}\right)D$ where N is an integer, the value of N is ___

[4 Sep, 2020 (Shift-II)]

140. A point object in air is in front of the curved surface of a plano-convex lens. The radius of curvature of the curved surface is 30 cm and the refractive index of the lens material is 1.5, then the focal length of the lens (in cm) is ____. **[8 Jan, 2020 (Shift-I)]**

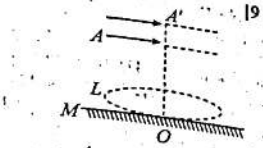
141. A convex lens is put 10 cm from a light source and it makes a sharp image on a screen, kept 10 cm from the lens. Now a glass block (refractive index 1.5) of 1.5 cm thickness is placed in contact with the light source. To get the sharp image again, the screen is shifted by a distance d. Then d is: **[9 Jan, 2019 (Shift-I)]**

(a) 1.1 cm away fro the lens (b) 0
(c) 0.55 cm towards the lens (d) 0.55 cm away from the lens

@FAKE_CBSE_X@RAJ_EDUNET

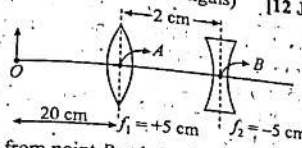
142. An upright object is placed at a distance of 40 cm in front of a convergent lens of focal length 20 cm. A convergent mirror of focal length 10 cm is placed at a distance of 60 cm on the other side of the lens. The position and size of the final image will be:
[8 April, 2019 (Shift-I)]
(a) 40 cm form the convergent mirror, same size as the object
(b) 20 cm form the convergent mirror, same size as the object
(c) 40 cm form the convergent lens, twice size of the object
(d) 20 cm from the convergent mirror, twice the size of the object

143. A thin convex lens L (refractive index = 1.5) is placed on a plane mirror M. When a pin is placed at A, such that $OA = 18$ cm, its real inverted image is formed at A itself, as shown in figure. When a liquid of refractive index μ_1 is put between the lens and the mirror, The pin has to be moved to A', such that $OA' = 27$ cm, to get its inverted real image at A' itself. The value of μ_1 will be:
[9 April, 2019 (Shift-II)]



(a) $\sqrt{2}$ (b) $\frac{4}{3}$ (c) $\sqrt{3}$ (d) $\frac{3}{2}$

144. What is the position and nature of image formed by lens combination shown in figure? (f_1, f_2 are focal lengths) **[12 Jan, 2019 (Shift-I)]**

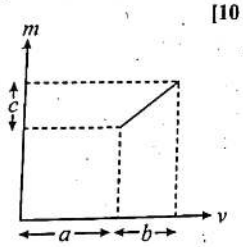


(a) 70 cm from point B at left; virtual
(b) 40 cm from point B at right; real
(c) $\frac{20}{3}$ cm from point B at right; real
(d) 70 cm from point B at right; real

145. A plano-convex lens (focal length f_2, refractive index μ_2, radius of curvature R) fits exactly into a plano-concave lens (focal length f_1, refractive index μ_1, radius of curvature R). Their plane surfaces are parallel to each other. Then, the focal length of the combination will be:
[12 Jan, 2019 (Shift-II)]
(a) $f_1 - f_2$ (b) $\frac{R}{\mu_2 - \mu_1}$ (c) $\frac{2f_1f_2}{f_1 + f_2}$ (d) $f_1 + f_2$

146. A convex lens of focal length 20 cm produces images of the same magnification 2 when an object is kept at two distances x_1 and x_2 ($x_1 > x_2$) from the lens. The ratio of x_1 and x_2 is:
[9 April, 2019 (Shift-II)]
(a) 5 : 3 (b) 2 : 1 (c) 4 : 3 (d) 3 : 1

147. The graph shows how the magnification m produced by a thin lens varies with image distance v. What is the focal length of the lens used?
[10 April, 2019 (Shift-II)]

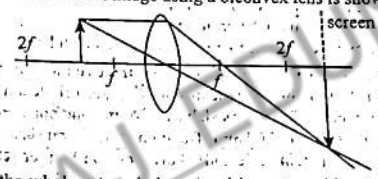


(a) $\frac{b^2c}{a}$ (b) $\frac{b^2}{ac}$
(c) $\frac{a}{c}$ (d) $\frac{b}{c}$

148. An object is at a distance of 20 m from a convex lens of focal length 0.3 m. The lens forms an image of the object. If the object moves away from the lens at a speed of 5 m/s, the speed and direction of the image will be:
[11 Jan, 2019 (Shift-I)]
(a) 2.26×10^{-3} m/s away from the lens
(b) 0.92×10^{-3} m/s away from the lens
(c) 3.22×10^{-3} m/s towards the lens
(d) 1.16×10^{-3} m/s towards the lens

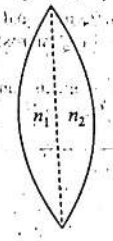
149. A plano convex lens of refractive index μ_1 and focal length f_1 is kept in contact with another plano concave lens of refractive index μ_2 and focal length f_2. If the radius of curvature of their spherical faces is R each and $f_1 = 2f_2$, then μ_1 and μ_2 are related as:
[10 Jan, 2019 (Shift-I)]
(a) $\mu_1 + \mu_2 = 3$ (b) $2\mu_1 - \mu_2 = 1$
(c) $3\mu_2 + \mu_1 = 1$ (d) $2\mu_2 + \mu_1 = 1$

150. Formation of real image using a biconvex lens is shown below :



If the whole set up is immersed in water without disturbing the object and the screen positions, what will one observe on the screen?
[12 Jan, 2019 (Shift-II)]
(a) Image disappears (b) Magnified image
(c) Erect real image (d) No change

151. A thin convex lens is made of two materials with refractive indices n_1 and n_2, as shown in figure. The radius of curvature of the left and right spherical surfaces are equal. f is the focal length of the lens when $n_1 = n_2 = n$. The focal length is $f + \Delta f$ when $n_1 = n$ and $n_2 = n + \Delta n$. Assuming $\Delta n << (n - 1)$ and $1 < n < 2$, the correct statement(s) is/are: **[JEE Advance 2019]**



(a) The relation between $\frac{\Delta f}{f}$ and $\frac{\Delta n}{n}$ remains unchanged if both the convex surfaces are replaced by concave surfaces of the same radius of curvature.
(b) $\left|\frac{\Delta f}{f}\right| < \left|\frac{\Delta n}{n}\right|$
(c) For $n = 1.5$, $\Delta n = 10^{-3}$ and $f = 20$cm, the value of $|\Delta f|$ will be 0.02 cm (round off to 2nd decimal place)
(d) If $\frac{\Delta n}{n} < 0$, then $\frac{\Delta f}{f} > 0$

@FAKE-OSCEX @RAJEDUNET

152. An optical bench has 1.5 m long scale having four equal divisions in each cm. While measuring the focal length of a convex lens, the lens is kept at 75 cm mark of the scale and the object pin is kept at 45 cm mark. The image of the object pin on the other side of the lens overlaps with image pin that is kept at 135 cm mark. In this experiment, the percentage error in the measurement of the focal length of the lens is_____. **[JEE Advance 2019]**

Optical Instrument

153. A microscope is focused on an object at the bottom of a bucket. If liquid with refractive index $\frac{5}{3}$ is poured inside the bucket, then microscope have to be raised by 30 cm to focus the object again. The height of the liquid in the bucket is: **[31 Jan, 2023 (Shift-II)]**

(*a*) 75 cm (*b*) 50 cm (*c*) 18 cm (*d*) 12 cm

154. In a reflecting telescope, a secondary mirror is used to: **[8 Apr, 2023 (Shift-I)]**

(*a*) reduce the problem of mechanical support
(*b*) remove spherical aberration
(*c*) make chromatic aberration zero
(*d*) move the eyepiece outside the telescopic tube

155. In an experiment of measuring the refractive index of a glass slab using travelling microscope in a physics lab, a student measures the real thickness of the glass slab as 5.25 mm and apparent thickness of the glass slab as 5.00 mm. Travelling microscope has 20 divisions in one cm on main scale and 50 divisions on Vernier scale is equal to 49 divisions on main scale. The estimated uncertainty in the measurement of refractive index of the slab is $\frac{x}{10}\times10^{-3}$, where x is_____. **[29 Jan, 2023 (Shift-II)]**

156. In normal adjustment, for a refracting telescope, the distance between objective and eye piece is 30 cm. The focal length of the objective, when the angular magnification of the telescope is 2, will be: **[28 July, 2022 (Shift-I)]**

(*a*) 20 cm (*b*) 30 cm (*c*) 10 cm (*d*) 15 cm

157. A travelling microscope is used to determine the refractive index of a glass slab. If 40 divisions are there in 1 cm on main scale and 50 Vernier scale divisions are equal to 49 main scale divisions, then least count of the travelling microscope is _____ $\times 10^{-6}$ m. **[26 June, 2022 (Shift-II)]**

158. Given below are two statements : one is labeled as **Assertion A** and the other is labeled as **Reason R.[** **26 Feb, 2021 (Shift-II)]**

Assertion A : For a simple microscope, the angular size of the object equals the angular size of the image.

Reason R : Magnification is achieved as the small object can be kept much closer to the eye than 25 cm and hence it subtends a large angle.

In the light of the above statements, choose the most appropriate answer from the options given below:

(*a*) Both A and R are true and R is the correct explanation of A
(*b*) Both A and R are true but R is NOT the correct explanation of A
(*c*) A is false but R is true
(*d*) A is true but R is false

159. An object viewed from a near point distance of 25 cm, using a microscopic lens with magnification '6', gives an unresolved image, A resolved image is observed at infinite distance with a total magnification double the earlier using an eyepiece along with the given lens and a tube of length 0.6 m, if the focal length of the eyepiece is equal to _____cm. **[20 July, 2021 (Shift-I)]**

160. If we need a magnification of 375 from a compound microscope of tube length 150 mm and an objective of focal length 5 mm, the focal length of the eye piece should be close to **[7 Jan, 2020 (Shift-I)]**

(*a*) 22 mm (*b*) 33 m (*c*) 12 m (*d*) 2 mm

161. The magnifying power of a telescope with tube length 60 cm is 5. What is the focal length of its eye piece? **[8 Jan, 2020 (Shift-I)]**

(*a*) 30 cm (*b*) 10 cm (*c*) 40 cm (*d*) 20 cm

162. In a compound microscope, the magnified virtual image is formed at a distance of 25 cm from the eye-piece. The focal length of its objective lens is 1 cm. If the magnification is 100 and the tube length of the microscope is 20 cm, then the focal length of the eye-piece lens (in cm) is _____. **[4 Sep, 2020 (Shift-I)]**

163. A compound microscope consists of an objective lens of focal length 1 cm and an eyepiece of focal length 5 cm with a separation of 10 cm.

The distance between an object and the objective lens at which the stain on the eye is minimum is $\frac{n}{40}$ cm. The value of n is ____. **[5 Sep, 2020 (Shift-I)]**

164. The value of numerical aperture of the objective lens of a microscope is 1.25. If light of wavelength 5000Å is used, the minimum separation between two points, to be seen as distinct, will be: **[12 April, 2019 (Shift-I)]**

(*a*) 0.24 μm (*b*) 0.38 μm (*c*) 0.12 μm (*d*) 0.48 μm

165. The wavelength of the carrier waves in a modern optical fiber communication network is close to: **[8 April, 2019 (Shift-I)]**

(*a*) 600 nm (*b*) 900 nm (*c*) 2400 nm (*d*) 1500 nm

@MAKE BOOK ON TELEGRAM

JEE-Advanced

Plane Mirror

Single Correct

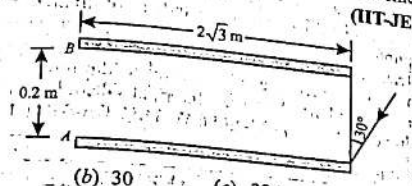
1. A ray of light travelling in the direction $1/2\,(\hat{i}+\sqrt{3}\hat{j})$ is an incident on a plane mirror. After reflection, it travels along the direction $1/2\,(\hat{i}-\sqrt{3}\hat{j})$. The angle of incidence is

C-33.8 W-65.1 UA-1.1 (JEE Adv. 2013)

(a) 30° (b) 45° (c) 60° (d) 75°

2. Two plane mirrors A and B are aligned parallel to each other, as shown in the figure. A light ray is incident at an angle 30° at a point just inside one end of A. The plane of incidence coincides with the plane of the figure. The maximum number of times the ray undergoes reflections (including the first one) before it emerges out is

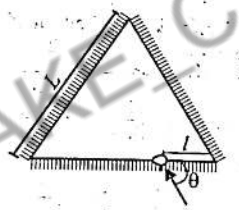
(IIT-JEE 2002)



(a) 28 (b) 30 (c) 32 (d) 34

Multiple Correct

3. Three plane mirrors form an equilateral triangle with each side of length L. There is a small hole at a distance $l>0$ from one of the corners as shown in the figure. A ray of light is passed through the hole at an angle θ and can only come out through the same hole. The cross section of the mirror configuration and the ray of light lie on the same plane. **C-9.15 W-25.49 UA-53.13 (JEE Adv. 2022)**



Which of the following statement(s) is/are correct?

(a) The ray of light will come out for $\theta = 30°$, for $0 < l < L$.

(b) There is an angle for $l = \frac{L}{2}$ at which the ray of light will come out after two reflections.

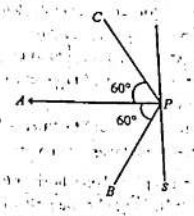
(c) The ray of light will never come out for $\theta = 60°$, and $l = \frac{L}{3}$.

(d) The ray of light will come out for $\theta = 60°$, and $0 < l < \frac{L}{2}$ after six reflections.

Numerical Types/Integer Types

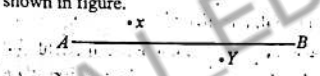
4. Screen S is illuminated by two point sources A and B. Another source C sends a parallel beam of light towards point P on the screen (see figure). Line AP is normal to the screen and the lines AP, BP and CP are in one plane. The distances AP and BP are 3m and 1.5m. The radiant powers of sources A and B are 90 W and 180 W respectively. The beam from C is of intensity 20 W/m². Calculate intensity at P on the screen.

(IIT-JEE 1982)



Subjective

5. An image Y is formed of point object X by a lens whose optic axis is AB as shown in figure.



Draw a ray diagram to locate the lens and its focus. If the image Y of the object X is formed by a concave mirror (having the same optic axis as AB) instead of lens, draw another ray diagram to locate the mirror and its focus. Write down the steps of construction of the ray diagrams.

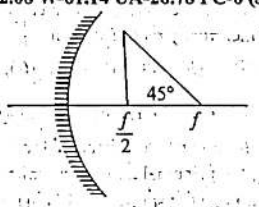
(IIT-JEE 1994)

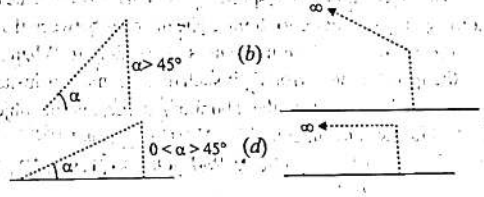
Spherical Mirrors

Single Correct

6. A wire is bent in the shape of a right angled triangle and is placed in front of a concave mirror of focal length f as shown in the figure. Which of the figures shown in the four options qualitatively represent(s) the shape of the image of the bent wire? (These figures are not to scale.)

C-12.08 W-61.14 UA-26.78 PC-0 (JEE Adv. 2018)





@FAKE_CBSE_KA_NEET_EDUNEXT

7. In an experiment to determine the focal length (f) of a concave mirror by the $u-v$ method, a student places the object point A on the principal axis at a distance x from the pole P. The student looks at the pin and its inverted image from a distance keeping his/her eye in line with PA. When the student shifts his/her eye towards left, the image appears to the right of the object pin. Then **(IIT-JEE 2007)**

(a) $x<f$ (b) $f<x<2f$ (c) $x=2f$ (d) $x>2f$

8. **Statement-I:** The formula connecting u, v and f for a spherical mirror is valid only for mirrors whose sizes are very small compared to their radii of curvature.

Statement-II: Laws of reflection are strictly valid for plane surfaces, but not for large spherical surfaces. **(IIT-JEE 2007)**

(a) If Statement-I is true, Statement-II is true; Statement-II is the correct explanation for Statement-I.

(b) If Statement-I is true, Statement-II is true; Statement-II is not a correct explanation for Statement-I

(c) If Statement-I is true; Statement-II is false.

(d) If Statement-I is false; Statement-II is true.

9. A concave mirror is placed on a horizontal table with its axis directed vertically upwards. Let O be the pole of the mirror and C its centre of curvature. A point object is placed at C. It has a real image, also located at C. If the mirror is now filled with water, the image will be **(JEE Adv. 1998)**

(a) real and will remain at C

(b) real and located at a point between C and ∞

(c) virtual and located at a point between C and O

(d) real and located at a point between C and O

10. A diminished image of an object is to be obtained on a screen 1.0 m from it. This can be achieved by placing **(JEE Adv. 1995)**

(a) a plane mirror

(b) a convex mirror of suitable focal length

(c) a convex lens of focal length less than 0.25 m

(d) a concave lens of suitable focal length

Multiple Correct

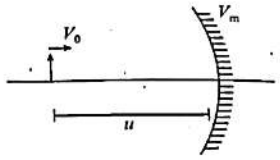
11. A student performed the experiment of determination of focal length of a concave mirror by u-v method using an optical bench of length 1.5 m. The focal length of the mirror used is 24 cm. The maximum error in the location of the image can be 0.2 cm. The 5 sets of (u,v) values recorded by the student (in cm) are: (42,56), (48,48), (60,40), (66,33), (78,39). The data set(s) that cannot come from experiment and is/are incorrectly recorded, is/are **(IIT-JEE 2009)**

(a) (42, 56) (b) (48, 48) (c) (66, 33) (d) (78, 39)

Numerical Types/Integer Types

12. An object and a concave mirror of focal length f = 10 cm both move along the principal axis of the mirror with constant speeds. The object moves with speed $V_0 = 15$ cm s^{-1} towards the mirror with respect to a laboratory frame. The distance between the object and the mirror at a given moment is denoted by **u**. When **u** = 30 cm, the speed of the mirror V_m is such that the image is instantaneously at rest with respect to the laboratory frame, and the object forms a real image. The magnitude of V_m is ____ cms^{-1}.

C-6.93 W-21.68 UA-71.39 [JEE Adv. 2022]



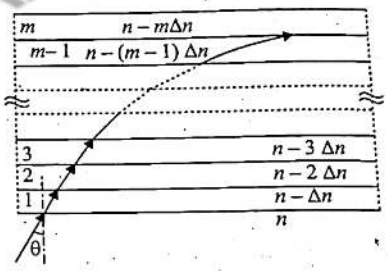
Fill In the Blanks

13. A thin rod of length $f/3$ is placed along the optic axis of a concave mirror of focal length f such that its image which is real and elongated, just touches the rod. The magnification is ..... **(IIT-JEE 1991)**

Refraction from Plane Surface

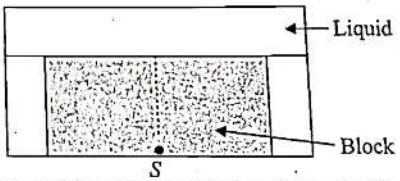
Single Correct

14. A monochromatic light is travelling in a medium of refractive index $n = 1.6$. It enters a stack of glass layers from the bottom side at an angle $\theta = 30°$. The interfaces of the glass layers are parallel to each other. The refractive indices of different glass layers are monotonically decreasing as $nm = n - m\Delta n$, where $n - m$ is the refractive index of the m^{th} slab and $\Delta n = 0.1$ (see the figure). The ray is refracted out parallel to the interface between the $(m-1)^{th}$ and m^{th} slabs from the right side of the stack. What is the value of m? **C-29.56 W-64.57 UA-5.87 (JEE Adv. 2017)**



(a) 8 (b) 9 (c) 10 (d) 11

15. A point source S is placed at the bottom of a transparent block of height 10mm and refractive index 2.72.



It is immersed in a lower refractive index liquid as shown in the figure. It is found that the light emerging from the block to the liquid forms a circular bright spot of diameter 11.54mm on the top of the block. The refractive index of the liquid is

C-19.62 W-24.51 UA-55.87 (JEE Adv. 2014)

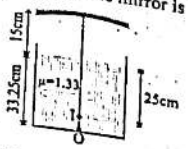
(a) 1.21 (b) 1.30 (c) 1.36 (d) 1.42

16. A large glass slab ($\mu = 5/3$) of thickness 8 cm is placed over a point source of light on a plane surface. It is seen that light emerges out of the top surface of the slab from a circular area of radius R cm. What is the value of R? **(IIIT-JEE 2010)**

(a) 6 cm (b) 7 cm (c) 8 cm (d) 9 cm

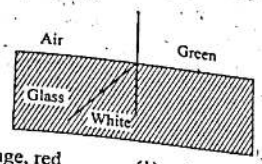
@BYKE_CBSE_X @RAJ_BYJUNET

17. A container is filled with water ($\mu = 1.33$) up to a height of 33.25 cm. A concave mirror is placed 15 cm above the water level and the image of an object placed at the bottom is formed 25 cm below the water level. The focal length of the mirror is **(IIT-JEE 2005)**



(a) 10 cm (b) 15 cm (c) 20 cm (d) 25 cm

18. White light is incident on the interface of glass and air as shown in the figure. If green light is just totally internally reflected then the emerging ray in air contains. **(IIT-JEE 2004)**

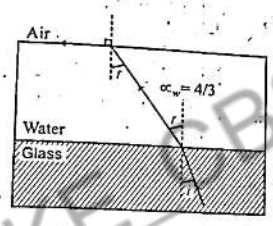


(a) yellow, orange, red (b) violet, indigo, blue
(c) all colours (d) all colours except green

19. A point object is placed at the centre of a glass sphere of radius 6 cm and refractive index 1.5. The distance of the virtual image from the surface of the sphere is **(IIT-JEE 2004)**

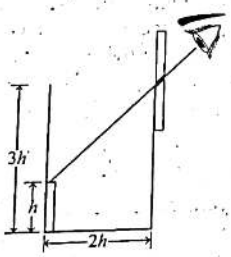
(a) 2 cm (b) 4 cm (c) 6 cm (d) 12 cm

20. A ray of light is incident at the glass-water interface at an angle i, it emerges finally parallel to the surface of water, then the value of μ_g would be **(IIT-JEE 2003)**



(a) $\frac{4}{3}\sin i$ (b) $\frac{1}{\sin i}$ (c) $\frac{4}{3}$ (d) 1

21. An observer can see through a pin-hole the top end of a thin rod of height h, placed as shown in the figure. The beaker height is $3h$ and its radius h. When the beaker is filled with a liquid up to a height $2h$, he can see the lower end of the rod. Then the refractive index of the liquid is **(IIT-JEE 2002)**

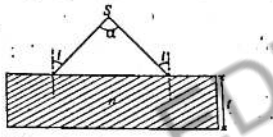


(a) $\frac{5}{2}$ (b) $\sqrt{\frac{5}{2}}$ (c) $\sqrt{\frac{3}{2}}$ (d) $\frac{3}{2}$

22. A ray of light passes through four transparent media with refractive indices μ_1, μ_2, μ_3 and μ_4 as shown in the figure. The surfaces of all media are parallel. If the emergent ray CD is parallel to the incident ray AB, we must have **(IIT-JEE 2001)**

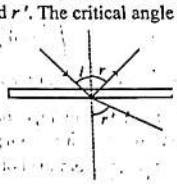
(a) $\mu_1 = \mu_2$ (b) $\mu_2 = \mu_3$ (c) $\mu_3 = \mu_4$ (d) $\mu_4 = \mu_1$

23. A diverging beam of light from a point source S having divergence angle α falls symmetrically on a glass slab as shown. The angles of incidence of the two extreme rays are equal. If the thickness of the glass slab is t and its refractive index is n, then the divergence angle of the emergent beam is **(IIT-JEE 2000)**



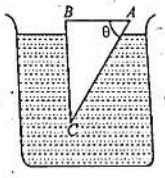
(a) zero (b) α
(c) $\sin^{-1}(1/n)$ (d) $2\sin^{-1}(1/n)$

24. A ray of light from a denser medium strikes a rarer medium at an angle of incidence i (see figure). The reflected and refracted rays make an angle of 90° with each other. The angles of reflection and refraction are r and r'. The critical angle is **(IIT-JEE 1983)**



(a) $\sin^{-1}(\tan r)$ (b) $\sin^{-1}(\cot i)$
(c) $\sin^{-1}(\tan r')$ (d) $\tan^{-1}(\sin i)$

25. A glass prism of refractive index 1.5 is immersed in water (refractive index 4/3). A light beam incident normally on the face AB is totally reflected to reach the face BC if **(IIT-JEE 1981)**



(a) $\sin\theta > 8/9$ (b) $2/3 < \sin\theta < 8/9$
(c) $\sin\theta < 2/3$ (d) None of these

26. When a ray of light enters a glass slab from air **(IIT-JEE 1980)**

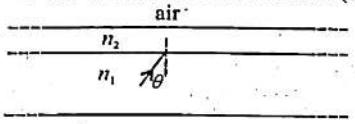
(a) its wavelength decreases
(b) its wavelength increases
(c) its frequency increases
(d) neither its wavelength nor its frequency changes

@FAKE_CBSE_GMAIL.COM

Multiple Correct

27. A wide slab consisting of two media of refractive indices n_1 and n_2 is placed in air as shown in the figure. A ray of light is incident from medium n_1 to n_2 at an angle θ, where $\sin\theta$ is slightly larger than $\frac{1}{n_1}$. Take refractive index of air as 1. Which of the following statement(s) is/are correct?

C-7.67 W-31.95 UA-29.72 PC-30.66 (JEE Adv. 2021)



(a) The light ray enters air if $n_2 = n_1$

(b) The light ray is finally reflected back into the medium of refractive index n_1 if $n_2 < n_1$

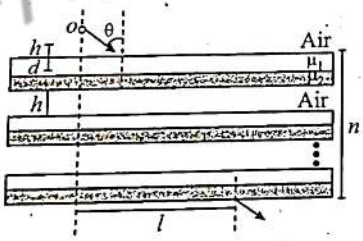
(c) The light ray is finally reflected back into the medium of refractive index n_1; if $n_2 > n_1$

(d) The light ray is reflected back into the medium of refractive index n_1 if $n_2 = 1$

Numerical Types/Integer Types

28. Consider a configuration of **n** identical units, each consisting of three layers. The first layer is a column of air of height $\mathbf{h} = \frac{1}{3}$ cm, and the second and third layers are of equal thickness $\mathbf{d} = \frac{\sqrt{3}-1}{2}$ cm, and refractive indices $\mu_1 = \sqrt{\frac{3}{2}}$ and $\mu_2 = \sqrt{3}$, respectively. A light source **O** is placed on the top of the first unit, as shown in the figure. A ray of light from **O** is incident on the second layer of the first unit at an angle of $\theta = 60°$ to the normal. For a specific value of **n**, the ray of light emerges from the bottom of the configuration at a distance $l = \frac{8}{\sqrt{3}}$ cm, as shown in the figure. The value of **n** is _____.

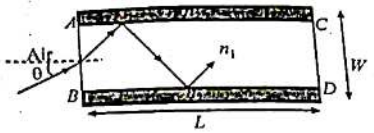
C-7.42 W-11.3 UA-81.28 (JEE Adv. 2022)



29. A planar structure of length **L** and width **W** is made of two different optical media of refractive indices $\mathbf{n}_1 = 1.5$ and $\mathbf{n}_2 = 1.44$ as shown in figure. If **L >> W**, a ray entering from end **AB** will emerge from end **CD** only if the total internal reflection condition is met inside the structure. For **L** = 9.6 m, if the incident angle θ is varied, the maximum time taken by a ray to exit the plane **CD** is $\mathbf{t} \times 10^{-9}$ s, where **t** is _____.

[Speed of light $c = 3 \times 10^8$ m/s]

C-1 W-69 UA-30 (JEE Adv. 2019)



Comprehension/Passage Based

Passage (30-31): Most materials have the refractive index, $n > 1$. So, when a light ray from air enters a naturally occurring material, then by Snell's law, $(\sin\theta_1)/(\sin\theta_2) = n_2/n_1$, it is understood that the refracted ray bends towards the normal. But it never emerges on the same side of the normal as the incident ray. According to electromagnetism, the refractive index of the medium is given by the relation, $n = (c/v) = \pm\sqrt{(\varepsilon_r\mu_r)}$, where c is the speed of electromagnetic waves in vacuum, v its speed in the medium, ε_r and μ_r are the relative In normal materials, both ε_r and μ_r are positive, implying positive n for the medium. When both ε_r and μ_r are negative, one must choose the negative root of n. Such negative refractive index materials can now be artificially prepared and are called meta-materials. They exhibit significantly different optical behaviour, without violating any physical laws. Since n is negative, it results in a change in the direction of propagation of the refracted light. However, similar to normal materials, the frequency of light remains unchanged upon refraction even in meta-materials. **(IIT-JEE 2012)**

30. Choose the correct statement.

(a) The speed of light in the meta-material is $v = c|n|$

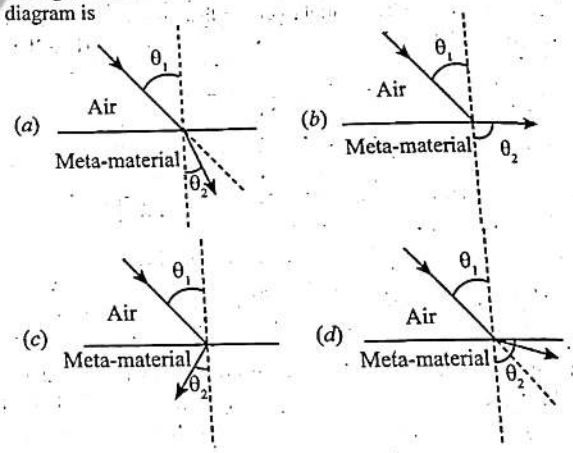
(b) The speed of light in the meta-material is $v = c/|n|$

(c) The speed of light in the meta-material is $v = c$

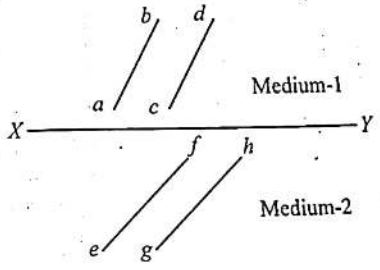
(d) The wavelength of the light in the meta-material (λ_m) is given by $\lambda_m = \lambda_{air}/|n|$, where λ_{air} is the wavelength of the light in air.

Incorrect

31. For light incident from air on a meta-material, the appropriate ray diagram is



Passage (32-34): The figure shows a surface *XY* separating two transparent media, medium-1 and medium-2. The lines *ab* and *cd* represent wavefronts of a light wave travelling in medium-1 and incident on *XY*. The lines *ef* and *gh* represent wavefronts of the light wave in medium-2 after refraction. **(IIT-JEE 2007)**



@FAKE_COURSE_X@RAMDUM

34. Light travels as a
(a) parallel beam in each medium
(b) convergent beam in each medium
(c) divergent beam in each medium
(d) divergent beam in one medium and convergent beam in the other medium

35. The phases of the light wave at c, d, e and f are ϕ_c, ϕ_d, ϕ_e, and ϕ_f respectively. It is given that $\phi_e \neq \phi_f$
(a) ϕ_c cannot be equal to ϕ_d
(b) ϕ_d can be equal to ϕ_e
(c) $(\phi_d - \phi_f)$ is equal to $(\phi_c - \phi_e)$
(d) $(\phi_d - \phi_c)$ is not equal to $(\phi_f - \phi_e)$

36. Speed of light is
(a) the same in medium-1 and medium-2
(b) larger in medium-1 than in medium-2
(c) larger in medium-2 than in medium-1
(d) different at b and d

Fill in the Blanks

35. If ε_0 and μ_0 are, respectively, the electric permittivity and magnetic permeability of free space, ε and μ the corresponding quantities in a medium, the index of refraction of the medium in terms of the above parameters is ..... **(IIT-JEE 1992)**

36. A slab of material of refractive index 2 shown in figure has a curved surface APB of radius of curvature 10 cm and a plane surface CD. On the left of APB is air and on the right of CD is water with refractive indices as given in the figure. An object O is placed at a distance of 15 cm from the pole P as shown. The distance of the final image of O from P, as viewed from the left is ..... **(IIT-JEE 1991)**

37. A monochromatic beam of light of wavelength 6000Å in vacuum enters a medium of refractive index 1.5. In the medium its wavelength is ....., and its frequency is ..... **(IIT-JEE 1985)**

38. A light wave of frequency 5×10^{14} Hz enters a medium of refractive index 1.5. In the medium the velocity of the light wave is ..... and its wavelength is ..... **(IIT-JEE 1983)**

Subjective

39. A glass plate of refractive index 1.5 is coated with a thin layer of thickness t and refractive index 1.8. Light of wavelength λ travelling in air is incident normally on the layer. It is partly reflected at the upper and the lower surfaces of the layer and the two reflected rays interfere.

Write the condition for their constructive interference. If $\lambda = 648$ nm, obtain the least value of t for which the rays interfere constructively. **(IIT-JEE 2000)**

40. The x-y plane is the boundary between two transparent media. Medium-1 with $z \geq 0$ has a refractive index $\sqrt{2}$ and medium-2 with $z \leq 0$ has a refractive index $\sqrt{3}$. A ray of light in medium-1 given by vector $A = 6\sqrt{3}\hat{i} + 8\sqrt{3}\hat{j} - 10\hat{k}$ is incident on the plane of separation. Find the unit vector in the direction of the refracted ray in medium-2. **(IIT-JEE 1999)**

41. A ray of light travelling in air is incident at grazing angle (Incident angle = 90°) on a long rectangular slab of a transparent medium of thickness $t = 1.0$ m. The point of incidence is the origin $A(0, 0)$. The medium has a variable index of refraction $n(y)$ given by $n(y)$ [$ky^{3/2} + 1]^{1/2}$ where $k = 1.0\ (\text{m})^{-3/2}$.

The refractive index of air is 1.0. **(IIT-JEE 1995)**

(a) Obtain a relation between the slope of the trajectory of the ray at a point $B(x, y)$ in the medium and the incident angle at that point.

(b) Obtain an equation for the trajectory $y(x)$ of the ray in the medium.

(c) Determine the coordinates (x_1, y_1) of the point P, where the ray intersects the upper surface of the slab-air boundary.

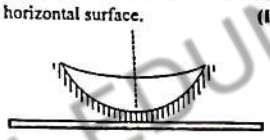
(d) Indicate the path of the ray subsequently.

42. A parallel beam of light travelling in water (refractive index = 4/3) is refracted by a spherical air bubble of radius 2 mm situated in water. Assuming the light rays to be para-axial. **(IIT-JEE 1988)**

(a) Find the position of the image due to refraction at the first surface and the position of the final image.

(b) Draw a ray diagram showing the positions of both the images

43. The convex surface of a thin concavo-convex lens of glass of refractive index 1.5 has a radius of curvature 20 cm. The concave surface has a radius of curvature 60 cm. The convex side is silvered and placed on a horizontal surface. **(IIT-JEE 1981)**



(a) Where should a pin be placed on the optic axis such that its image is formed at the same place?

(b) If the concave part is filled with water of refractive index 4/3, find the distance through which the pin should be moved, so that the image of the pin again coincides with the pin.

44. The radius of curvature of the convex face of a planoconvex lens is 12 cm and its $\mu = 1.5$ **(IIT-JEE 1979)**

(a) Find the focal length of the lens. The plane face of the lens is now silvered.

(b) At what distance from the lens will parallel rays incident on the convex surface converge ?

(c) Sketch the ray diagram to locate the image, when a point object is placed on the axis 20 cm from the lens.

(d) Calculate the image distance when the object is placed as in (c)

Total Internal Reflection and Critical Angle

Single Correct

45. If two structures of same cross-sectional area, but different numerical apertures NA_1 and NA_2 ($NA_2 < NA_1$) are joined longitudinally, the numerical aperture of the combined structure is **(JEE Adv. 2015)**

(a) $(NA_1 < NA_2)/(NA_1 + NA_2)$

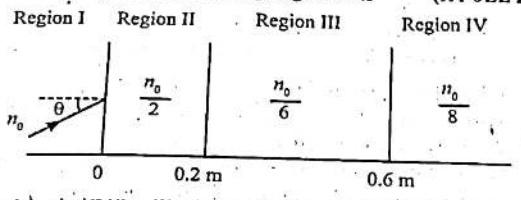
(b) $NA_1 + NA_2$

(c) NA_1

(d) NA_2

@FREE_CBSE_@RU_EDUNET

46. A light beam is travelling from Region I to Region IV (Refer Figure). The refractive index in Regions I, II, III and IV are n_0, $\frac{n_0}{2}$, $\frac{n_0}{6}$ and $\frac{n_0}{8}$ respectively. The angle of incidence θ for which the beam just misses entering Region IV is **(IIT-JEE 2008)**



(a) $\sin^{-1}(3/4)$ (b) $\sin^{-1}(1/8)$ (c) $\sin^{-1}(1/4)$ (d) $\sin^{-1}(1/3)$

47. A ray of light travelling in water is incident on its surface open to air. The angle of incidence is θ, which is less than the critical angle. Then there will be **(IIT-JEE 2007)**

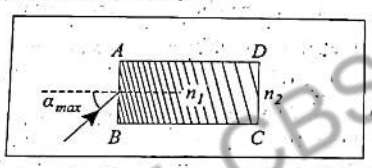
(a) only a reflected ray and no refracted ray.

(b) only a refracted ray and no reflected ray

(c) a reflected ray and a refracted ray and the angle between them would be less than 180°–2θ

(d) a reflected ray and a refracted ray and the angle between them would be greater than 180° – 2θ° Incorrect

48. A rectangular glass slab *ABCD* of refractive index n_1 is immersed in water of refractive index $n_2(n_1 > n_2)$. A ray of light is incident at the surface *AB* of the slab as shown. The maximum value of the angle of incidence α_{max}, such that the ray comes out only from the other surface *CD*, is given by **(IIT-JEE 2000)**



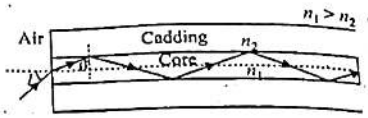
(a) $\sin^{-1}\left[\frac{n_1}{n_2}\cos\left(\sin^{-1}\frac{n_2}{n_1}\right)\right]$ (b) $\sin^{-1}\left[n_1\cos\left(\sin^{-1}\frac{1}{n_2}\right)\right]$

(c) $\sin^{-1}\left(\frac{n_1}{n_2}\right)$ (d) $\sin^{-1}\left(\frac{n_2}{n_1}\right)$

Multiple Correct

49. Light guidance in an optical fibre can be understood by considering a structure comprising of thin solid glass cylinder of refractive index n_1 surrounded by a medium of lower refractive index n_2. The light guidance in the structure takes place due to successive total internal reflections at the interface of the media n_1 and n_2 as shown in the figure. All rays with the angle of incidence i less than a particular value i_m are confined in the medium of refractive index n_1. The numerical aperture (*NA*) of the structure is defined as $\sin i_m$.

For two structures namely S_1 with $n_1 = \sqrt{45}/4$ and $n_2 = 3/2$, and S_2 with $n_1 = 8/5$ and $n_2 = 7/5$ and taking the refractive index of water to be 4/3 and that to air to be 1, the correct options is/are **(JEE Adv. 2015)**



(a) *NA* of S_1 immersed in water is the same as that of S_2 immersed in a liquid of refractive index $16/(3\sqrt{15})$

(b) *NA* of S_1 immersed in liquid of refractive index $6/\sqrt{15}$ is the same as that of S_2 immersed in water

(c) *NA* of S_1 placed in air is the same as that S_2 immersed in liquid of refractive index $4/\sqrt{15}$

(d) *NA* of S_1 placed in air is the same as that of S_2 placed in water

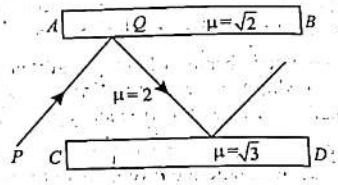
50. A ray of light travelling in a transparent medium falls on a surface separating the medium from air at an angle of incidence 45°. The ray undergoes total internal reflection. If n is the refractive index of the medium with respect to air, select the possible value (s) of n from the following **(IIT-JEE 1998)**

(a) 1.3 (b) 1.4

(c) 1.5 (d) 1.6

Numerical Types/Integer Types

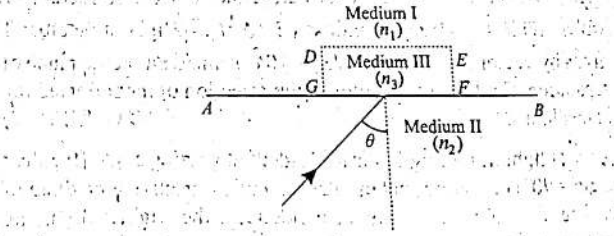
51. *AB* and *CD* are two slabs. The medium between the slabs has refractive index 2. Find the minimum angle of incidence at Q, so that the ray is totally reflected by both the slabs. **(IIT-JEE 2005)**



Subjective

52. Monochromatic light is incident on a plane interface *AB* between two media of refractive indices n_1 and n_2 $(n_2 > n_1)$ at an angle of incidence θ as shown in the figure.

The angle θ is infinitesimally greater than the critical angle for the two media so that total internal reflection takes place. Now if a transparent slab *DEFG* of uniform thickness and of refractive index n_3 is introduced on the interface (as shown in the figure), show that for any value of n_3 all light will ultimately be reflected back again into medium II.



Consider separately the cases : **(IIT-JEE 1986)**

(a) $n_3 < n_1$ and (b) $n_3 > n_1$

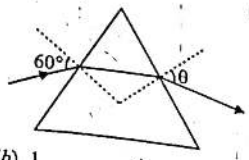
@FAKE CBSE X @MJEDUMT

Prism

Single Correct

53. A monochromatic beam of light is incident at 60° on one face of an equilateral prism of refractive index n and emerges from the opposite face making an angle $\theta(n)$ with the normal (see figure). For $n = \sqrt{3}$ the value of $\theta(n)$ is 60° and $\frac{d\theta}{dn} = m$. The value of m is

(JEE Adv. 2015)



(a) 2 (b) 1 (c) 3 (d) 4

54. Two beams of red and violet colours are made to pass separately through a prism (angle of the prism is 60°). In the position of minimum deviation, the angle of refraction will be (IIT-JEE 2008)

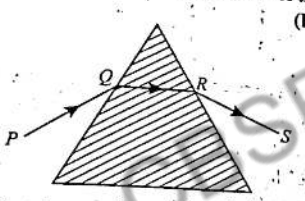
(a) 30° for both the colours

(b) greater for the violet colour

(c) greater for the red colour

(d) equal but not 30° for both the colours

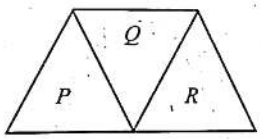
55. A ray of light is incident on an equilateral glass prism placed on a horizontal table. For minimum deviation which of the following is true? (IIT-JEE 2004)



(a) PQ is horizontal (b) QR is horizontal

(c) RS is horizontal (d) Either PQ or RS is horizontal

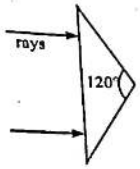
56. A given ray of light suffers minimum deviation in an equilateral prism P. Additional prisms Q and R of identical shape and of the same material as P are now added as shown in the figure. The ray will suffer (IIT-JEE 2001)



(a) greater deviation (b) no deviation

(c) same deviation as before (d) total internal reflection

57. An isosceles prism of angle 120° has a refractive index 1.44. Two parallel rays of monochromatic light enter the prism parallel to each other in air as shown. The rays emerging from the opposite face (IIT-JEE 1995)



(a) are parallel to each other

(b) are diverging

(c) make an angle 2 [$\sin^{-1}(0.72) - 30°$] with each other

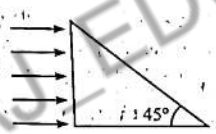
(d) make an angle $2\sin^{-1}(0.72)$ with each other

58. A thin prism P_1 with angle 4° and made from glass of refractive index 1.54 is combined with another thin prism P_2 made from glass of refractive index 1.72 to produce dispersion without deviation. The angle of the prism P_2 is (IIT-JEE 1990)

(a) 5.33° (b) 4° (c) 3° (d) 2.6°

59. A beam of light consisting of red, green and blue colours is incident on a right-angled prism. The refractive indices of the material of the prism for the above red, green and blue wavelengths are 1.39, 1.44 and 1.47 respectively.

The prism will (IIT-JEE 1989)



(a) separate the red colour from the green and blue colours

(b) separate the blue colour from the red and green colours

(c) separate all the three colours from one another

(d) not separate even partially any colour from the other two colours.

Multiple Correct

60. A plane polarized blue light ray is incident on a prism such that there is no reflection from the surface of the prism. The angle of deviation of the emergent ray is $\delta = 60°$ Fig. 1. The angle of minimum deviation for red light from the same prism is $\delta_{min} = 30°$ Fig. 2. The refractive index of the prism material for blue light is $\sqrt{3}$. Which of the following statements is/are correct?

C-2.23 W-17.39 UA-56.01 PC-24.37 (JEE Adv. 2023)

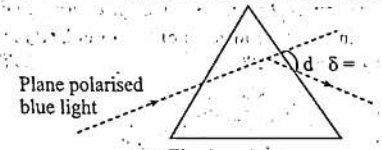


Fig. 1.

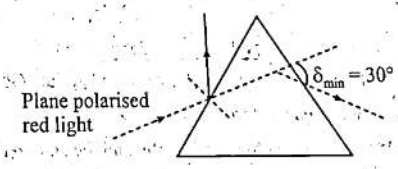


Fig. 2.

@JEE_ONE_X_@RAJEEDUNET

(a) The blue light is polarized in the plane of incidence.

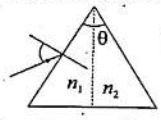
(b) The angle of the prism is 45°.

(c) The refractive index of the material of the prism for red light is $\sqrt{2}$.

(d) The angle of refraction for blue light in air at the exit plane of the prism is 60°.

61. For a prism of prism angle $\theta = 60°$, the refractive indices of the left half and the right half are, respectively, n_1 and $n_2 (n_2 \geq n_1)$ as shown in the figure. The angle of incidence i is chosen such that the incident light rays will have minimum deviation if $n_1 = n_2 = n = 1.5$. For the case of unequal refractive indices, $n_1 = n$ and $n_2 = n + \Delta n$, the angle of emergence $e = i + \Delta e$. Which of the following statement(s) is/are correct?

C-3.5 W-22.57 UA-64.06 PC-9.87(JEE Adv. 2021)



(a) The value of Δe (in radians) is greater than that of Δn

(b) Δe is proportional to Δn

(c) Δe lies between 2.0 and 3.0 milli-radians, if $\Delta n = 2.8 \times 10^{-3}$

(d) Δe lies between 1.0 and 1.6 milli-radians, if $\Delta n = 2.8 \times 10^{-3}$

62. For an isosceles prism of angle A and refractive index μ, it is found that the angle of minimum deviation $\delta_m = A$. Which of the following options is/are correct?

C-5.95 W-14.35 UA-36.33 PC-43.37 (JEE Adv. 2017)

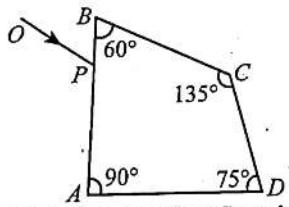
(a) For the angle of incidence $i_1 = A$, the ray inside the prism is parallel to the base of the prism

(b) For this prism, the refractive index μ and the angle prism A are related as $A = \frac{1}{2}\cos^{-1}\left(\frac{\mu}{2}\right)$

(c) For this prism, the emergent ray at the second surface will be tangential to the surface when the angle of incidence at the first surface is $\sin^{-1}\left[\sin A\sqrt{4\cos^2\frac{A}{2}-1}-\cos A\right]$

(d) At minimum deviation, the incident angle i_1 and the refracting angle r_1 at the first refracting surface are related by $r_1 = (i_1/2)$

63. A ray OP of monochromatic light is incident on the face AB of prism $ABCD$ near vertex B at an incident angle of 60° (see figure). If the refractive index of the material of the prism is $\sqrt{3}$, which of the following is/are correct? **(IIT-JEE 2010)**



(a) The ray gets totally internally reflected at face CD

(b) The ray comes out through face AD

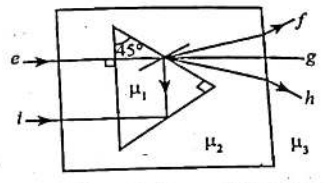
(c) The angle between the incident ray and the emergent ray is 90°

(d) The angle between the incident ray and the emergent ray is 120°

Match the Column

64. A right angled prism of refractive index μ_1 is placed in a rectangular block of refractive index μ_2, which is surrounded by a medium of refractive index μ_3, as shown in the figure, A ray of light 'e' enters the rectangular block at normal incidence. Depending upon the relationships between μ_1, μ_2 and μ_3, it takes one of the four possible paths 'e_f', 'e_g', 'e_h' or 'e_i'.

C-59.66 W-29.01 UA-11.33 (JEE Adv. 2013)



Match the paths in Column-I with conditions of refractive indices in Column-II and select the correct answer using the codes given below the lists.

Column-I	Column-II
P. e to f	1. $\mu_1 > \sqrt{2}\,\mu_2$
Q. e to g	2. $\mu_2 > \mu_1$ and $\mu_2 > \mu_3$
R. e to h	3. $\mu_1 = \mu_2$
S. e to i	4. $\mu_2 < \mu_1 < \sqrt{2}\,\mu_2$ and $\mu_2 > \mu_3$

Codes:

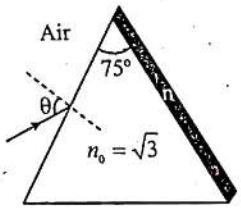
	P	Q	R	S
(a)	2	3	1	4
(b)	1	2	4	3
(c)	4	1	2	3
(d)	2	3	4	1

Numerical Types/Integer Types

65. A monochromatic light is incident from air on a refracting surface of a prism of angle 75° and refractive index $n_0 = \sqrt{3}$. The other refracting surface of a prism is coated by a thin film of material of refractive index n as shown in figure. The light suffers total internal reflection at the coated prism surface for an incidence angle of $\theta \leq 60°$.

The value of n^2 is_____.

C-19.69 W-65.79 UA-14.51 (JEE Adv. 2019)



66. A ray of light is incident at an angle of 60° on one face of a prism which has an angle of 30°. The ray emerging out of the prism makes an angle of 30° with the incident ray. Show that the emergent ray is perpendicular to the face through which it emerges and calculate the refractive index of the material of the lens. **(IIT-JEE 1978)**

@FAKE CBSE X @RAJ BRUNET

Fill in the Blanks

67. A ray of light is incident normally on one of the faces of a prism of apex angle 30° and refractive index $\sqrt{2}$. The angle of deviation of the ray is ..... degrees. **(IIT-JEE 1997)**

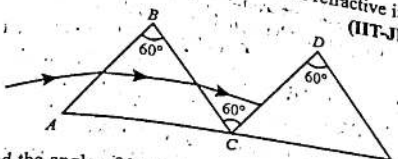
68. A ray of light undergoes deviation of 30° when incident on an equilateral prism of refractive index $\sqrt{2}$. The angle made by the ray inside the prism with the base of the prism is .... **(IIT-JEE 1992)**

True/False

69. A beam of white light passing through a hollow prism give no spectrum. **(IIT-JEE 1983)**

Subjective

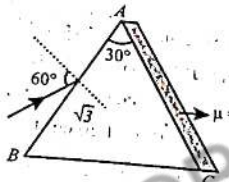
70. A ray of light is incident on a prism ABC of refractive index $\sqrt{3}$ as shown in figure. **(IIT-JEE 2005)**



(a) Find the angle of incidence for which the deviation of light ray by the prism ABC is minimum.

(b) By what angle the second identical prism must be rotated, so that the final ray suffers net minimum deviation.

71. A prism of refracting angle 30° is coated with a thin film of transparent material of refractive index 2.2 on face AC of the prism. A light of wavelength 6600 Å is incident on face AB such that angle of incidence is 60°. Find **(IIT-JEE 2003)**



(a) the angle of emergence and

(b) the minimum value of thickness of the coated film on the face AC for which the light emerging from the face has maximum intensity.

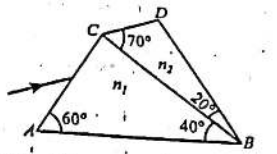
(Given refractive index of the material of the prism is $\sqrt{3}$)

72. The refractive indices of the crown glass for blue and red light are 1.51 and 1.49 respectively and those of the flint glass are 1.77 and 1.73 respectively. An isosceles prism of angle 6° is made of crown glass. A beam of white light is incident at a small angle on this prism. The other flint glass isosceles prism is combined with the crown glass prism such that there is no deviation of the incident light. **(IIT-JEE 2001)**

(a) Determine the angle of the flint glass prism.

(b) Calculate the net dispersion of the combined system.

73. A prism of refractive index n_1 and another prism of refractive index n_2 are stuck together with a gap as shown in the figure. The angles of the prism are as shown. n_1 and n_2 depend on λ, the wavelength of light according to: **(IIT-JEE 2000)**

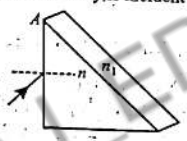


$$n_1 = 1.20 + \frac{10.8 \times 10^4}{\lambda^2} \text{ and } n_2 = 1.45 + \frac{1.80 \times 10^4}{\lambda^2}$$

(a) Calculate the wavelength λ_0 for which rays incident at any angle on the interface BC pass through without bending at that interface.

(b) For light of wavelength λ_0, find the angle of incidence i on the face AC such that the deviation produced by the combination of prisms is minimum.

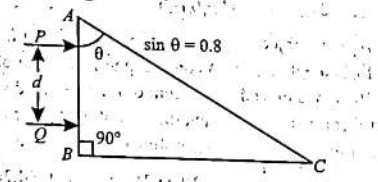
74. A right angled prism (45°– 90°– 45°) of refractive index n has a plane of refractive index $n_1 (n_1 < n)$ cemented to its diagonal face. The assembly is in air. The ray is incident on AB. **(IIT-JEE 1996)**



(a) Calculate the angle of incidence at AB for which the ray strikes the diagonal face at the critical angle.

(b) Assuming $n = 1.352$, calculate the angle of incidence at AB for which the refracted ray passes through the diagonal face undeviated.

75. Two parallel beams of light P and Q (separation d) containing radiations of wavelengths 4000 Å and 5000Å (which are mutually coherent in each wavelength separately) are incident normally on a prism as shown in figure.



The refractive index of the prism as a function of wavelength is given by the relation, $\mu(\lambda) = 1.20 + \frac{b}{\lambda^2}$ where λ is in Å and b is positive constant. The value of b is such that the condition for total reflection at the face AC is just satisfied for one wavelength and is not satisfied for the other. **(IIT-JEE 1991)**

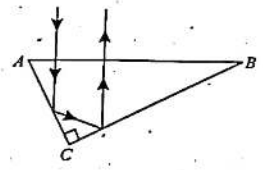
(a) Find the value of b.

(b) Find the deviation of the beams transmitted through the face AC.

(c) A convergent lens is used to bring these transmitted beams into focus. If the intensities of the upper and the lower beams immediately after transmission from the face AC, are $4I$ and I respectively, find the resultant intensity at the focus.

©TAKE CBSE X @SAJEEDUET

76. A right angled prism is to be made by selecting a proper material and the angles A and B ($B \le A$), as shown in figure. It is desired that a ray of light incident on the face AB emerges parallel to the incident direction after two internal reflections. **(IIT-JEE 1987)**



(*a*) What should be the minimum refractive index μ for this to be possible?

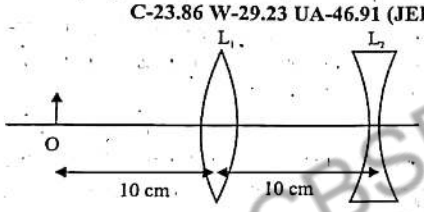
(*b*) For $\mu = \frac{5}{3}$ is it possible to achieve this with the angle B equal to 30 degrees?

Refraction at Curved Surface, Lens

Single Correct

77. An extended object is placed at point O, 10 cm in front of a convex lens L_1 and a concave lens L_2 is placed 10 cm behind it, as shown in the figure. The radii of curvature of all the curved surfaces in both the lenses are 20 cm. The refractive index of both the lenses is 1.5. The total magnification of this lens system is

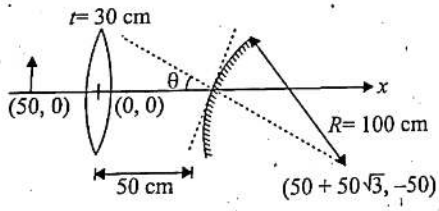
C-23.86 W-29.23 UA-46.91 (JEE Adv. 2022)



(*a*) 0.4 (*b*) 0.8 (*c*) 1.3 (*d*) 1.6

78. A small object is placed 50 m to the left of a thin convex lens of focal length 30 cm. A convex spherical mirror of radius of curvature 100 cm is placed to the right of the lens at a distance of 50 cm. The mirror is tilted such that the axis of the mirror is at an angle $\theta = 30°$ to the axis of the lens, as shown in the figure.

C-10.51 W-35.24 UA-54.26 (JEE Adv. 2016)

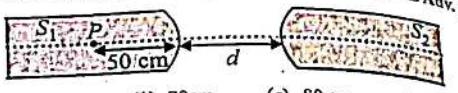


If the origin of the coordinate system is taken to be at the center of the lens, the coordinates (in cm) of the point (x, y) at which the image is formed are

(*a*) $(125/3, 25/\sqrt{3})$ (*b*) $(50 - 25\sqrt{3}, 25)$

(*c*) $(0, 0)$ (*d*) $(25, 25\sqrt{3})$

79. Two identical glass rods S_1 and S_2 (refractive index = 1.5) have one convex end of radius of curvature 10 cm. They are placed with the curved surfaces at a distance d as shown in the figure, with their axes (shown by the dashed line) aligned. When a point source of light P is placed inside rod S_1 on its axis at a distance of 50 cm from the curved face, the light rays emanating from it are found to be parallel to the axis inside S_2. The distance d is **(JEE Adv. 2015)**



(*a*) 60 cm (*b*) 70cm (*c*) 80 cm (*d*) 90 cm

80. Sunlight of intensity 1.3kWm^{-2} is incident normally on a thin convex lens of focal length 20 cm. Ignore the energy loss of light due to the lens and assume that the lens aperture size is much smaller than its focal length. The average intensity of light, in kWm^{-2}, at a distance 22 cm from the lens on the other side is

C-4.06 W-73.03 UA-22.91 (JEE Adv. 2018)

(*a*) 130 kW/m^2 (*b*) 131 kW/m^2

(*c*) 132 kW/m^2 (*d*) 133 kW/m^2

81. The image of an object, formed by a plano-convex lens at a distance of 8 m behind the lens, is real and is one-third the size of the object. The wavelength of light inside the lens is 2/3 times the wavelength in free space. The radius of the curved surface of the lens is

C-33.23 W-61.78 UA-4.99 (JEE Adv. 2013)

(*a*) 1 m (*b*) 2 m (*c*) 3 m (*d*) 6 m

82. A biconvex lens of focal length 15 cm is in front of a plane mirror. The distance between the lens and the mirror is 10 cm. A small object is kept at a distance of 30 cm from the lens. The final image is **(IIT-JEE 2010)**

(*a*) virtual and at a distance of 16 cm from the mirror

(*b*) real and at a distance of 16 cm from the mirror

(*c*) virtual and at a distance of 20 cm from the mirror

(*d*) real and at a distance of 20 cm from the mirror

83. A biconvex lens of focal length f forms a circular image of radius r of sun in focal plane. Then which option is correct? **(IIT-JEE 2006)**

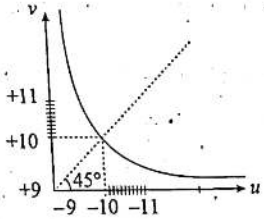
(*a*) $\pi r^2 \propto f$

(*b*) $\pi r^2 \propto f^2$

(*c*) If lower half part is covered by black sheet, then area of the image is equal to $\pi r^2 / 2$

(*d*) If f is doubled, intensity will increase

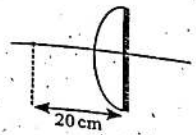
84. The graph between object distance u and image distance v for a lens is given below. The focal length of the lens is **(IIT-JEE 2006)**



(*a*) 5 ± 0.1 (*b*) 5 ± 0.05 (*c*) 0.5 ± 0.1 (*d*) 0.5 ± 0.05

@IIT_CBSE_X@TALEDNET

85. A point object is placed at a distance of 20 cm from a thin plano-convex lens of focal length 15 cm. The plane surface of the lens is now silvered. The image created by the system is at **(IIT-JEE 2006)**



(a) 60 cm to the left of the system
(b) 60 cm to the right of the system
(c) 12 cm to the left of the system
(d) 12 cm to the right of the system

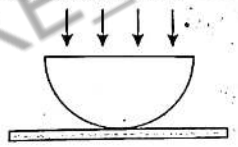
86. A convex lens is in contact with concave lens. The magnitude of the ratio of their focal length is 3/2. Their equivalent focal length is 30 cm. What are their individual focal lengths? **(IIT-JEE 2005)**
(a) −75, 50 (b) −10, 15 (c) 75, 50 (d) −15, 10

87. An object is approaching a thin convex lens of focal length 0.3 m with a speed of 0.01m/s. Find the magnitudes of the rates of change of position and lateral magnification of image when the object is at a distance of 0.4 m from the lens. **(IIT-JEE 2004)**
(a) $0.09\frac{m}{s}$ (b) $0.19\frac{m}{s}$ (c) $0.29\frac{m}{s}$ (d) $-0.09\frac{m}{s}$

88. The size of the image of an object, which is at infinity, as formed by a convex lens of focal length 30 cm is 2 cm. If a concave lens of focal length 20 cm is placed between the convex lens and the image at a distance of 26 cm from the convex lens, calculate the new size of the image. **(IIT-JEE 2003)**
(a) 1.25 cm (b) 2.5 cm (c) 1.05 cm (d) 2 cm

89. A hollow double concave lens is made of very thin transparent material. It can be filled with air or either of two liquids L_1 or L_2 having refracting indices n_1 and n_2 respectively ($n_2 > n_1 > 1$). The lens will diverge a parallel beam of light if it is filled with **(IIT-JEE 2000)**
(a) air and placed in air (b) air and immersed in L_1
(c) L_1 and immersed in L_2 (d) L_2 and immersed in L_1

90. A thin slice is cut out of a glass cylinder along a plane parallel to its axis. The slice is placed on a flat plate as shown. The observed interference fringes from this combination shall be **(IIT-JEE 1999)**



(a) straight
(b) circular
(c) equally spaced
(d) having fringe spacing which increases as we go outwards

91. A concave lens of glass, refractive index 1.5 has both surfaces of same radius of curvature R. On immersion in a medium of refractive index 1.75, it will behave as a **(IIT-JEE 1999)**
(a) convergent lens of focal length 3.5 R
(b) convergent lens of focal length 3.0 R
(c) divergent lens of focal length 3.5 R
(d) divergent lens of focal length 3.0 R

92. A spherical surface of radius of curvature R, separates air (refractive index 1.0) from glass (refractive index 1.5). The centre of curvature is in the glass. A point object P placed in air is found to have a real image Q in the glass. The line PQ cuts the surface at a point O and $PO = OQ$. The distance PO is equal to **(IIT-JEE 1998)**
(a) 5 R (b) 3 R (c) 2 R (d) 1.5 R

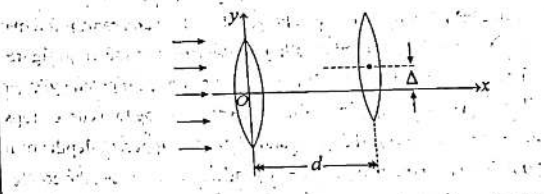
93. A real image of a distant object is formed by a plano-convex lens on its principal axis. Spherical aberration **(IIT-JEE 1998)**
(a) is absent
(b) is smaller if the curved surface of the lens faces the object
(c) is smaller if the plane surface of the lens faces the object
(d) is the same whichever side of the lens faces the object

94. An eye specialist prescribes spectacles having combination of convex lens of focal length 40 cm in contact with a concave lens of focal length 25 cm. The power of this lens combination in diopters is **(IIT-JEE 1997)**
(a) +1.5 (b) −1.5 (c) +6.67 (d) −6.67

95. A diminished image of an object is to be obtained on a screen 1.0 m from it. This can be achieved by placing **(IIT-JEE 1995)**
(a) a plane mirror
(b) a convex mirror of suitable focal length
(c) a convex lens of focal length less than 0.25 m
(d) a concave lens of suitable focal length

96. Spherical aberration in a thin lens can be reduced by **(IIT-JEE 1994)**
(a) using a monochromatic light
(b) using a doublet combination
(c) using a circular annular mark over the lens
(d) increasing the size of the lens

97. Two thin convex lenses of focal lengths f_1 and f_2 are separated by a horizontal distance d (where $d < f_1$, $d < f_2$) and their centres are displaced by a vertical separation Δ as shown in the figure. Taking the origin of coordinates, O, at the centre of the first lens, the x and y-coordinates of the focal point of this lens system, for a parallel beam of rays coming from the left, are given by **(IIT-JEE 1993)**



(a) $x = \frac{f_1 f_2}{f_1 + f_2}, y = \Delta$

(b) $x = \frac{f_1(f_2 + d)}{f_1 + f_2 - d}, y = \frac{\Delta}{f_1 + f_2}$

(c) $x = \frac{f_1 f_2 + d(f_1 - d)}{f_1 + f_2 - d}, y = \frac{\Delta(f_1 - d)}{f_1 + f_2 - d}$

(d) $x = \frac{f_1 f_2 + d(f_1 - d)}{f_1 + f_2 - d}, y = 0$

@FAKE_CR7_@RAJ_BUNET

98. A convex lens of focal length 40 cm is in contact with a concave lens of focal length 25 cm. The power of the combination is

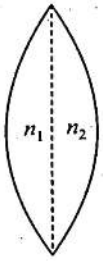
(IIT-JEE 1982)

(a) -1.5 D (b) -6.5 D (c) $+6.5$ D (d) $+6.67$ D

Multiple Correct

99. A thin convex lens is made of two materials with refractive indices n_1 and n_2, as shown in figure. The radius of curvature of the left and right spherical surfaces are equal. f is the focal length of the lens when $n_1 = n_2 = n$. The focal length is $f + \Delta f$ when $n_1 = n$ and $n_2 = n + \Delta n$. Assuming $\Delta n << (n-1)$ and $1 < n < 2$, the correct statement(s) is/are:

C-3 W-19 UA-53 PC-25 (JEE Adv. 2019)



(a) The relation between $\frac{\Delta f}{f}$ and $\frac{\Delta n}{n}$ remains unchanged if both the convex surfaces are replaced by concave surfaces of the same radius of curvature.

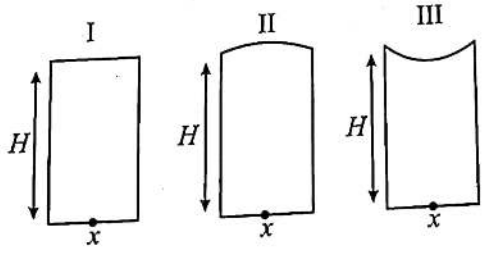
(b) $\left|\frac{\Delta f}{f}\right| < \left|\frac{\Delta n}{n}\right|$

(c) For $n = 1.5$, $\Delta n = 10^{-3}$ and $f = 20$cm, the value of $|\Delta f|$ will be 0.02 cm (round off to 2nd decimal place)

(d) If $\frac{\Delta n}{n} < 0$, then $\frac{\Delta f}{f} > 0$

100. Three glass cylinders of equal height **H** = 30 cm and same refractive index **n** = 1.5 are placed on a horizontal surfaces shown in figure. Cylinder I has a flat top, cylinder II has a convex top and cylinder III has a concave top. The radii of curvature of the two curved tops are same (R = 3 m). If H_1, H_2 and H_3 are the apparent depths of a point **X** on the bottom of the three cylinders, respectively, the correct statement(s) is/are

C-24.08 W-37.96 UA-29.65 PC-8.31 (JEE Adv. 2019)



(a) $H_3 > H_1$

(b) 0.8 cm $< (H_2 - H_1) < 0.9$ cm

(c) $H_2 > H_3$

(d) $H_2 > H_1$

101. A plano-convex lens is made of material of refractive index n. When a small object is placed 30 cm away in front of the curved surface of the lens, an image of double the size of the object is produced. Due to reflection from the convex surface of the lens, another faint image is observed at a distance of 10 cm away from the lens. Which of the following statement(s) is/are true?

C-8.43 W-26.38 UA-53.59 PC-11.6 (JEE Adv. 2016)

(a) The refractive index of the lens is 2.5

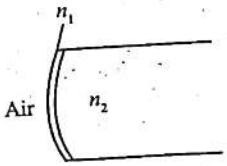
(b) The radius of curvature of the convex surface is 45 cm

(c) The faint image is erect and real

(d) The focal length of the lens is 20 cm

102. A transparent thin film of uniform thickness and refractive index $n_1 = 1.4$ is coated on the convex spherical surface of radius R at one end of a long solid glass cylinder of refractive index $n_2 = 1.5$, as shown in the figure. Rays of light parallel to the axis of the cylinder traversing through the film from air to glass get focused at distance f_1 from the film, while rays of light traversing from glass to air get focused at distance f_2 from the film. Then

C-21.4 W-66.76 UA-11.84 (JEE Adv. 2014)



(a) $|f_1| = 3R$ (b) $|f_1| = 2.8R$

(c) $|f_2| = 2R$ (d) $|f_2| = 1.4R$

103. Which of the following form(s) a virtual and erect image for all positions of the object ?

(IIT-JEE 1996)

(a) Convex lens

(b) Concave lens

(c) Convex mirror

(d) Concave mirror

104. A converging lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen

(IIT-JEE 1986)

(a) half of the image will disappear

(b) complete image will be formed

(c) intensity of the image will increase

(d) intensity of the image will decrease

105. List-I contains four c
focal lengths (in cm)
object is placed 20 cm
between the two lens
final images.

List-I

(I) O 20 cm 1

(II) O 20 cm

(III) O 20 c

(IV) O 20

Which one

(a) (I) –

(b) (I) –

(c) (I) –

(d) (I)

106. Four co
radius o
of all th
their fo
the co

(P)

(Q

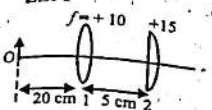
(

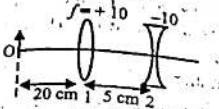
@FAKE_CBSE X @RAJEE_NET

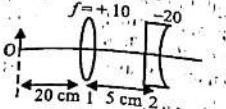
Match the Column

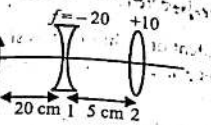
105. List-I contains four combinations of two lenses (1 and 2) whose focal lengths (in cm) are indicated in the figures. In all cases, the object is placed 20 cm from the first lens on the left, and the distance between the two lenses is 5 cm. List-II contains the positions of the final images. **C42.60 W22.98 UA34.41 (JEE Adv. 2022)**

List-I

(I) 

(II) 

(III) 

(IV) 

List-II

(P) Final image is formed at 7.5 cm on the right side of lens 2.

(Q) Final image is formed at 60.0 cm on the right side of lens 2.

(R) Final image is formed at 30.0 cm on the left side of lens 2.

(S) Final image is formed at 6.0 cm on the right side of lens 2.

(T) Final image is formed at 30.0 cm on the right side of lens 2.

Which one of the following options is correct?

(a) (I) → P; (II) → R; (III) → Q; (IV) → T

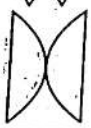
(b) (I) → Q; (II) → P; (III) → T; (IV) → S

(c) (I) →; ; (II) → T; (III) → R; (IV) → Q

(d) (I) → T; (II) → S; (III) → Q; (IV) → R

106. Four combinations of two thin lenses are given in Column-I. The radius of curvature of all curved surfaces is r and the refractive index of all the lenses is 1.5. Match lens combinations in Column-I with their focal length in Column-II and select the correct answer using the codes given below the lists.

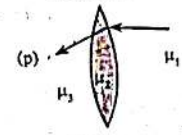
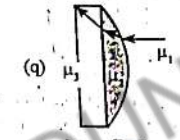
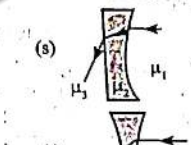
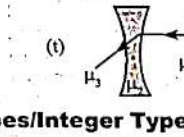
C-47.51 W-40.99 UA-11.5 (JEE Adv. 2014)

Column-I	Column-II
(P)	1. 2r
(Q) 	2. $\frac{r}{2}$
(R)	3. −r
(S)	4. r

(a) P-1,Q-2, R-3,S-4 (b) P-2, Q-4, R-3, S-1

(b) P-4,Q-1,R-2,S-3 (c) P-2, Q-1, R-3, S-4

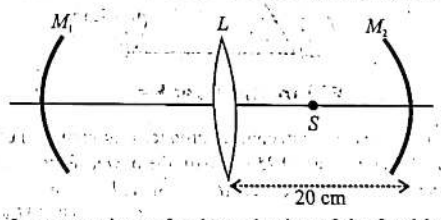
107. Two transparent media of refractive indices μ_1 and μ_3 have a solid lens shaped transparent material of refractive index μ_2 between them as shown in figures in Column-II. A ray traversing these media is also shown in the figures. In Column-I different relationships between μ_1,μ_2 and μ_3 are given. Match them to the ray diagram shown in Column-II. **(IIT JEE 2010)**

Column-I	Column-II
A. $\mu_1 < \mu_2$	(p) 
B. $\mu_1 > \mu_2$	(q) 
C. $\mu_3 = \mu_2$	(r)
D. $\mu_2 > \mu_3$	(s) 
	(t) 

Numerical Types/Integer Types

108. An optical arrangement consists of two concave mirrors M_1 and M_2, and a convex lens L with a common principal axis, as shown in the figure. The focal length of L is 10 cm. The radii of curvature of M_1 and M_2 are 20 cm and 24 cm, respectively. The distance between L and M_2 is 20 cm. A point object S is placed at the mid-point between L and M_2 on the axis. When the distance between L and M_1 is n/7cm, one of the images coincides with S. The value of n is

C-2.92 W-65.11 UA-31.97 (JEEE Adv. 2023)

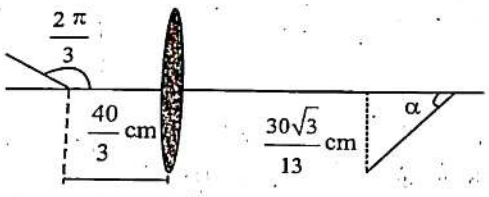


109. In an experiment for determination of the focal length of a thin convex lens, the distance of the object from the lens is 10 ± 0.1 cm and the distance of its real image from the lens is 20 ± 0.2 cm. The error in the determination of focal length of the lens is n%. The value of n is _____ **:C-15.12 W-68.51 UA-16.37 (JEE Adv. 2023)**

@FAKE_EDITX @RAJ_EDUNET

110. A rod of length 2 cm makes an angle $\frac{2\pi}{3}$ rad with the principal axis of a thin convex lens. The lens has a focal length of 10cm and is placed at a distance of $\frac{40}{3}$ cm from the object as shown in the figure. The height of the image is $\frac{30\sqrt{3}}{13}$ cm and the angle made by it with respect to the principal axis is α rad. The value of α is $\frac{\pi}{n}$ rad, where **n** is_____.

C-17.36 W-47.29 UA-35.34 (JEE Adv. 2022)

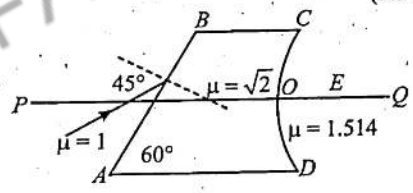


111. An optical bench has 1.5 m long scale having four equal divisions in each cm. While measuring the focal length of a convex lens, the lens is kept at 75 cm mark of the scale and the object pin is kept at 45 cm mark. The image of the object pin on the other side of the lens overlaps with image pin that is kept at 135 cm mark. In this experiment, the percentage error in the measurement of the focal length of the lens is_____.

C-0.4 W-76.12 UA-23.48 (JEE Adv. 2019)

112. A plano-convex lens has a thickness of 4 cm. When placed on a horizontal table, with the curved surface in contact with it, the apparent depth of the bottom most point of the lens is found to be 3 cm. If the lens is inverted such that the plane face is in contact with the table, the apparent depth of the centre of the plane face is found to be 25/8 cm. Find the focal length of the lens. Assume thickness to be negligible while finding its focal length. **(IIT-JEE 1984)**

113. Figure shows an irregular block of material of refractive index $\sqrt{2}$. A ray of light strikes the face AB as shown in the figure. After refraction it is incident on a spherical surface CD of radius of curvature 0.4 m and enters a medium of refractive index 1.514 to meet PQ at E. Find the distance OE upto two places of decimal. **(IIT-JEE 2004)**



Fill in the Blanks

114. Two thin lenses, when in contact, produce a combination of power + 10 D. When they are 0.25 m a part, the power reduces to + 6 D. The focal length of the lenses are ..... m and..... m. **(IIT-JEE 1997)**

115. A thin rod of length $f/3$ is placed along the optic axis of a concave mirror of focal length f such that its image which is real and elongated, just touches the rod. The magnification is .....

116. A thin lens of refractive index 1.5 has a focal length of 15 cm in air. When the lens is placed in a medium of refractive index 4/3, its focal length will become ..... cm. **(IIT-JEE 1987)**

117. A convex lens A of focal length 20 cm and a concave lens B of focal length 5 cm are kept along the same axis with a distance d between them. If a parallel beam of light falling on A leaves B as parallel beam, then d is equal to.....cm. **(IIT-JEE 1985)**

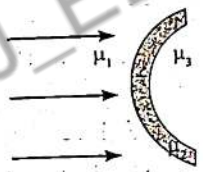
True/False

118. A parallel beam of white light fall on a combination of a concave and a convex lens, both of the same material. Their focal lengths are 15 cm and 30 cm respectively for the mean wavelength in white light. On the same side of the lens system, one sees coloured patterns with violet colour nearer to the lens. **(IIT-JEE 1988)**

119. A convex lens of focal length 1 m and a concave lens of focal length 0.25 m are kept 0.75 m apart. A parallel beam of light first passes through the convex lens, then through the concave lens and comes to a focus 0.5 m away from the concave lens. **(IIT-JEE 1983)**

Subjective

120. In the figure, light is incident on a thin lens as shown. The radius of curvature for both the surfaces is R. Determine the focal length of this system. **(IIT-JEE 2003)**

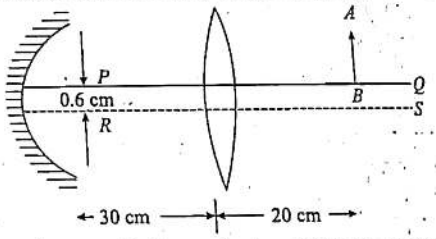


121. The refractive indices of the crown glass for blue and red light are 1.51 and 1.49 respectively and those of the flint glass are1.77 and 1.73 respectively. An isosceles prism of angle 6° is made of crown glass. A beam of white light is incident at a small angle on this prism. The other flint glass isosceles prism is combined with the crown glass prism such that there is no deviation of the incident light. **(IIT-JEE 2001)**

(*a*) Determine the angle of the flint glass prism.

(*b*) Calculate the net dispersion of the combined system.

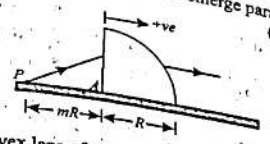
122. A convex lens of focal length 15 cm and a concave mirror of focal length 30 cm are kept with their optic axis PQ and RS parallel but separated in vertical direction by 0.6 cm as shown.



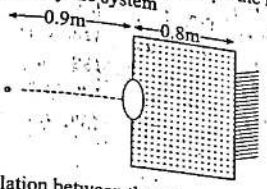
The distance between the lens and mirror is 30 cm. An upright object AB of height 1.2 cm is placed on the optic axis PQ of the lens at a distance of 20 cm from the lens. If $A'B'$ is the image after refraction from the lens and the reflection from the mirror, find the distance of $A'B'$ from the pole of the mirror and obtain its magnification. Also locate positions of A′ and B′ with respect to the optic axis RS.

@FAKE_CBSE_@RAJ_EBUNET

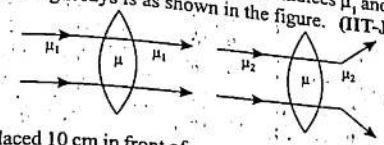
123. A quarter cylinder of radius R and refractive index 1.5 is placed on a table. A point object P is kept at a distance of mR from it. Find the value of m for which a ray from P will emerge parallel to the table as shown in figure. **(IIT-JEE 2000)**



124. A thin equi-convex lens of glass of refractive index $\mu = 3/2$ and of focal length 0.3 m in air is sealed into an opening at one end of a tank filled with water $\mu = 4/3$. On the opposite side of the lens, a mirror is placed inside the tank on the tank wall perpendicular to the lens axis, as shown in figure. The separation between the lens and the mirror is 0.8 m. A small object is placed outside the tank in front of lens. Find the position (relative to the lens) of the image of the object formed by the system **(IIT-JEE 1997)**



125. What is the relation between the refractive indices μ_1 and μ_2? If the behaviour of light rays is as shown in the figure. **(IIT-JEE 1979)**



126. A pin is placed 10 cm in front of a convex lens of focal length 20 cm and made of a material of refractive index 1.5. The convex surface of the lens farther away from the pin is silvered and has a radius of curvature of 22 cm. Determine the position of the final image. Is the image real or virtual? **(IIT-JEE 1978)**

Optical Instrument

Single Correct

127. The focal lengths of the objective and the eyepiece of a compound microscope are 2.0 cm and 3.0 cm respectively. The distance between the objective and the eyepiece is 15.0 cm. The final image formed by the eyepiece is at infinity. The two lenses are thin. The distance in cm of the object and the image produced by the objective, measured from the objective lens, are respectively **(IIT-JEE 1995)**

(a) 2.4 and 12.0
(b) 2.4 and 15.0
(c) 2.0 and 12.0
(d) 2.0 and 3.0

128. An astronomical telescope has an angular magnification of magnitude 5 for far objects. The separation between the objective and the eyepiece is 36 cm and the final image is formed at infinity. The focal length f_o of the objective and the focal length f_e of the eyepiece are **(IIT-JEE 1989)**

(a) $f_o = 45$ cm and $f_e = -9$ cm
(b) $f_o = 50$ cm and $f_e = 10$ cm
(c) $f_o = 7.2$ cm and $f_e = 5$ cm
(d) $f_o = 30$ cm and $f_e = 6$ cm

Multiple Correct

129. A planet is observed by an astronomical refracting telescope having an objective of focal length 16 m and an eyepiece of focal length 2 cm **(IIT-JEE 1992)**

(a) the distance between the objective and the eyepiece is 16.02 m
(b) the angular magnification of the planet is –800
(c) the image of the planet is inverted
(d) the objective is larger than the eyepiece

Match the Column

130. Some laws/processes are given in Column-I. Match these with the physical phenomena given in Column-II. **(IIT-JEE 2006)**

	Column-I		Column-II
(A)	Intensity of light received by lens	(p)	radius of aperture (R)
(B)	Angular magnification	(q)	dispersion of lens
(C)	Length of telescope	(r)	focal length $f_o f_e$
(D)	Sharpness of image	(s)	spherical aberration

Fill in the Blanks

131. The resolving power of electron microscope is higher than that of an optical microscope because the wavelength of electrons is ..... than the wavelength of visible light. **(IIT-JEE 1992)**

@FAKE-OBSERVER-RACE-DUNET

ANSWER KEY

JEE-Main

1. (a)	2. (b)	3. [18]	4. [98]	5. [210]	6. (a, b)	7. (d)	8. (c)	9. [150]	10. (c)
11. (b)	12. (a)	13. (c)	14. (c)	15. [32]	16. [32]	17. [80, 150, 220]		18. [400]	19. [3]
20. (d)	21. (d)	22. (c)	23. (c)	24. (d)	25. [1.00]	26. (b)	27. (d)	28. (a)	29. [31]
30. (b)	31. (b)	32. [52]	33. [50]	34. [3]	35. (b)	36. (a)	37. (a)	38. (d)	39. (c)
40. (c)	41. [12]	42. [9]	43. [15]	44. [4]	45. (d)	46. (d)	47. (b)	48. (c)	49. [158]
50. [2]	51. (b)	52. (d)	53. [2]	54. (a)	55. (b)	56. [5]	57. (d)	58. (a)	59. (d)
60. (a)	61. (b)	62. (d)	63. (a)	64. (b)	65. (a, b)	66. (b)	67. [50.00]	68. (d)	69. (a)
70. (a)	71. [2]	72. (d)	73. [30]	74. (a,c,d)	75. (a)	76. (d)	77. [27]	78. [4]	79. [12]
80. (a)	81. (a)	82. (b)	83. (b)	84. [600]	85. [60]	86. [5]	87. [05]	88. (a)	89. (c)
90. [1.50]	91. [200]	92. (b)	93. [120]	94. [30]	95. [225]	96. [10]	97. (c)	98. [30]	99. [90]
100. (d)	101. (a)	102. (d)	103. (c,d)	104. [3]	105. [10]	106. [20]	107. (b)	108. (a)	109. (c)
110. (a)	111. (a)	112. (c)	113. (d)	114. (b)	115. [5]	116. [4]	117. [30]	118. [34]	119. [100]
120. [54]	121. [1]	122. (a)	123. (b)	124. [10]	125. [10]	126. [15]	127. (c)	128. (a)	129. (c)
130. (d)	131. (c)	132. (a)	133. [15]	134. [50]	135. (c)	136. (d)	137. (d)	138. (a)	139. [476]
140. [60]	141. (c)	142. (*)	143. (b)	144. (d)	145. (b)	146. (d)	147. (d)	148. (d)	149. (b)
150. (a)	151. (a,c,d)	152. [1.39]	153. (a)	154. (d)	155. [41]	156. (a)	157. [5]	158. (a)	159. [25]
160. (a)	161. (b)	162. [6.25]	163. [50.00]	164. (a)	165. (d)				

JEE-Advanced

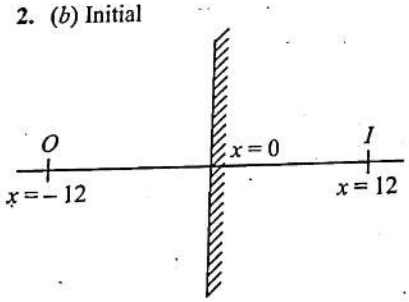
1. (a)	2. (b)	3. (a, b)	4. [13.97]	6. (d)	7. (b)	8. (a)	9. (d)	10. (c)	11. (c, d)
12. [3]	14. (a)	15. (c)	16. (a)	17. (c)	18. (a)	19. (c)	20. (b)	21. (b)	22. (d)
23. (b)	24. (a)	25. (a)	26. (a)	27. (b, c, d)	28. [4]	29. [50.00]	30. (b)	31. (b)	32. (a)
33. (c)	34. (b)	45. (d)	46. (b)	47. (c)	48. (a)	49. (a, c)	50. (c, d)	51. [60°]	53. (a)
54. (a)	55. (b)	56. (c)	57. (c)	58. (c)	59. (a)	60. (a, c, d)	61. (b, c)	62. (a, c, d)	63. (a, b, c)
64. (d)	65. [1.50]	66. [$\sqrt{3}$]	69. [True]	77. (b)	78. (d)	79. (b)	80. (a)	81. (c)	82. (b)
83. (b)	84. (b)	85. (c)	86. (d)	87. (a)	88. (b)	89. (d)	90. (a)	91. (a)	92. (a)
93. (b)	94. (b)	95. (c)	96. (c)	97. (c)	98. (a)	99. (a, c, d)	100. (c, d)	101. (a, d)	102. (a, c)
103. (b, c)	104. (b, d)	105. (a)	106. (b)	107. (A) → p, r (B) → q, s, t (C) → p, r, t (D) → q, s				108. [220]	109. [1]
110. [6]	111. [1.39]	112. [75]	113. [6.06]	118. [True]	119. [False]	127. (a)	128. (d)	129. (a, b, c, d)	
130. [(A) → p; (B) → r; (C) → r; (D) → p,q,r;]									

EXPLANATIONS

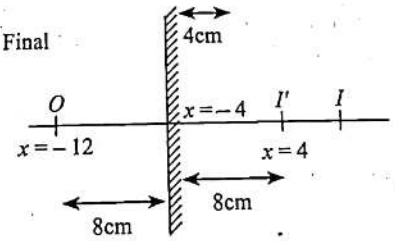
JEE-Main

1. (*a*) A plane mirror forms an erect, same sized, laterally inverted and virtual image of a real object.

2. (*b*) Initial



Final



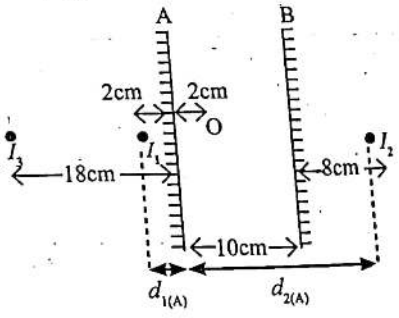
∴ Shifting of image = 12 − 4 = 8 cm

3. [18] I_1 is the first nearest image to A.

$d_{1(A)} = 2$ cm

I_2 is the second nearest image to A.

$d_{2(A)} = 18$ cm (Desired)

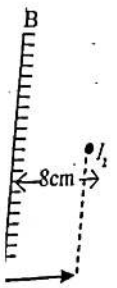


@FAKE_CBSE_KORI_EDUNET

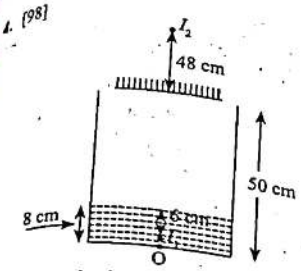
9. [150] 10. (c)
3. [400] 19. [3]
(a) 29. [31]
(d) 39. (c)
(c) 49. [158]
(a) 59. (d)
(d) 69. (a)
[4] 79. [12]
(a) 89. (c)
[30] 99. [90]
(a) 109. (c)
34] 119. [100]
a) 129. (c)
) 139. [476]
) 149. (b)
159. [25]

11. (c, d)
22. (d)
32. (a)
] 53. (a)
d) 63. (a, b, c)
82. (b)
92. (a)
102. (a, c)
109. [1]
d)

it image to A.
)



4. [98]



Apparent depth of

$$O = \frac{\text{real depth}}{\text{refractire index}} = \frac{d}{\mu} = 6$$

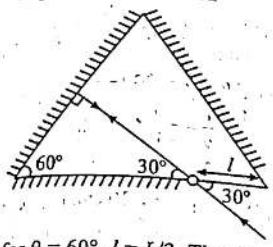
Distance between O and $I_2 = 48 + 50 = 98$ cm

5. [210]

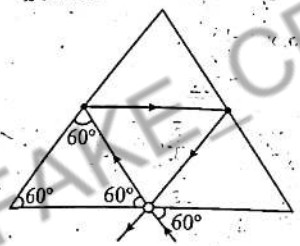
$\delta_{total} = 360^\circ - 2\theta = 360 - 2 \times 70^\circ = 210^\circ$

6. (a,b)

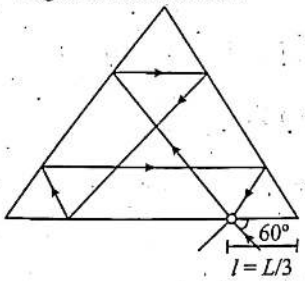
As we can see, for $\theta = 30^\circ$ the ray will incident normally and hence will retrace its path $\Rightarrow$ (a) is correct.



for $\theta = 60^\circ$, $l = L/2$. Then, we get ray diagram shown below. Clearly ray of light comes after two reflections $\Rightarrow$ (b) is correct.



If $\theta = 60^\circ$ and $l = L/3$, then we get ray diagram as shown below.



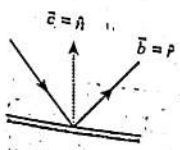
Clearly, after 5 reflections, ray comes out. So (c) and (d) are incorrect.

7. (d) $\vec{a} = \sin\theta\hat{i} - \cos\theta\hat{j}$

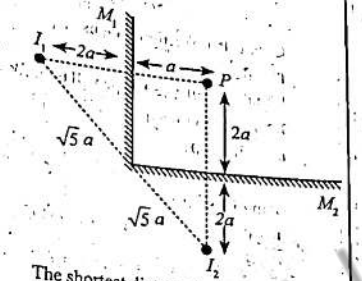
$\vec{b} = \sin\theta\hat{i} + \cos\theta\hat{j}$, $\vec{c} = \hat{j}$

New using the options

$\vec{a} - 2(\vec{a}\cdot\vec{c})\vec{c} = \vec{b}$



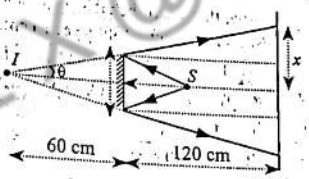
8. (c)



The shortest distance between the image thus formed, $I_1I_2 = 2\sqrt{5}a$

$= 2 \times 2.3\,a = 4.6\,a$

9. [150]



$\tan\theta = \frac{25}{60} = \frac{x}{180}$

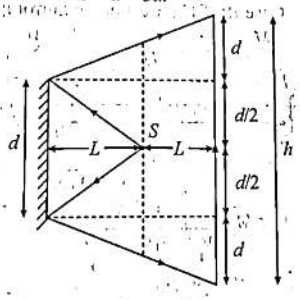
$x = 75$ cm

$\Rightarrow$ Maximum Distance $= 2x = 2 \times 75 = 150$ cm

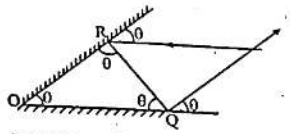
10. (c) So, the final distance is

$h = d + \frac{d}{2} + \frac{d}{2} + d = 3d.$

$h = d + d + d = 3d.$



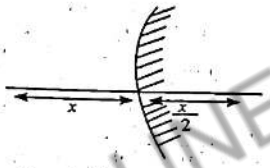
11. (b)



In ΔORQ, sum of all angles of triangle is 180°.

$\Rightarrow 0 + 0 + 0 = 180^\circ \Rightarrow 3\theta = 180^\circ \Rightarrow \theta = 60^\circ$

12. (a)



Given $R = 30$ cm

$f = R/2 = +15$ cm

image size is half the size of the object,

So, Magnification (m) $= \pm\frac{1}{2}$

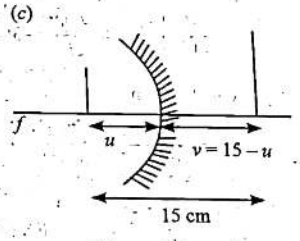
For convex mirror, virtual image is formed for real object.

Therefore, m is +ve

$\frac{1}{2} = \frac{f}{f-u} \Rightarrow f - u = 2f, u = -f$

$u = -15$ cm

13. (c)



$m = 2 = \frac{-v}{u}$

$2 = \frac{-(15-u)}{-u}$

$2u = 15 - u$

$3u = 15 \Rightarrow u = 5$ cm

$v = 15 - u = 15 - 5 = 10$ cm

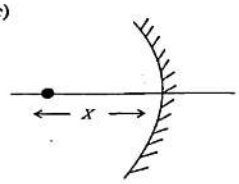
By using mirror formula

$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} = \frac{1}{10} + \frac{1}{(-5)} = \frac{1-2}{10} = \frac{-1}{10}$

The focal length of the mirror $f = -10$ cm

@FAKE_CBSE_X_@RAJ_EDUNET

14. (c)



Using mirror formula,

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{v_1}+\frac{1}{-15}=\frac{1}{(-20)}$$

$v_1 = 60$ cm

For the second object,

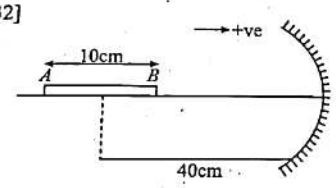
$$\frac{1}{v_2}+\frac{1}{(-25)}=\frac{1}{(-20)}$$

$$\frac{1}{v_2}=\frac{-1}{20}+\frac{1}{25}$$

$v_2 = -100\,cm$

$\Rightarrow d = 60+100 = 160\,cm$

15. [32]



$u_A = -45$ cm and $f = -20$ cm

$$v_A = \frac{-45\times(-20)}{-45-(-20)} = \frac{-900}{25} = -36 \text{ cm}$$

And $u_B = -35$ cm

$$\therefore\ v_B = \frac{-35\times(-20)}{-35-(-20)} = \frac{700}{-15}$$

$\therefore$ length of image $= v_A - v_B$

$$= \left(-36+\frac{140}{3}\right)\text{cm}, = \frac{32}{3}\text{ cm}$$

$\therefore x = 32$

16. [32] $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

$$\frac{-1}{120}-\frac{1}{40}=\frac{1}{f}, f=-30\text{cm}$$

Now,

$$\frac{-1}{v^2}dv-\frac{1}{u^2}du=-\frac{1}{f^2}df$$

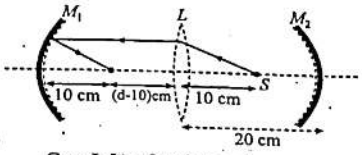
Also $dv = du = \frac{1}{20}$ cm

$$\therefore \frac{\frac{1}{20}}{(120)^2}+\frac{\frac{1}{20}}{(40)^2}=\frac{df}{(30)^2}$$

On solving $df = \frac{1}{32}$ cm

$\therefore K = 32$

17. [80, 150, 220]



Case I: Ist refraction on lens

Ist reflection at M_1

Light is parallel $\Rightarrow$ Image will be at focus.

IInd refraction from L

$u = -(d-10)$

$f = 10$ cm

Using lens formula.

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{v}+\frac{1}{d-10}=\frac{1}{10}$$

$$\frac{1}{v}=\frac{1}{10}-\frac{1}{(d-10)} \quad \ldots(i)$$

Now, this v will behave as an object for M_2, and image should be at 10 cm.

$$\frac{1}{u}+\frac{1}{v_1}=\frac{1}{f},\ -\frac{1}{(20-v)}-\frac{1}{10}=-\frac{1}{12}$$

$$\frac{1}{12}-\frac{1}{10}=\frac{1}{20-v}$$

$v = 80$ cm

From equation (i)

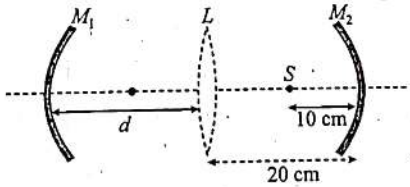
$$\frac{1}{80}=\frac{1}{10}-\frac{1}{d-10},\ \frac{1}{d-10}=\frac{1}{10}-\frac{1}{80}$$

$$\frac{1}{d-10}=\frac{80-10}{800}=\frac{70}{800}$$

$$d=\frac{150}{7}$$

$\boxed{n = 150}$

Case II: If Ist reflection on mirror m_2



For M_2 $\frac{1}{V_1}+\frac{1}{-10}=\frac{1}{-12}$

$\Rightarrow V_1 = 60$ cm

Then refraction on lens L, $u_2 = -80$ cm

$$\frac{1}{V_2}-\frac{1}{-60}=\frac{1}{10} \Rightarrow V_2=\frac{80}{7}$$

Then reflection on M_2

Either V_2 is at centre (normal incidence)

$$d-\frac{80}{7}=20,\ d=\frac{220}{7}$$

$$\frac{n}{7}=\frac{220}{7}$$

$n = 220$

V_2 is at pole of M_2

$$d-\frac{80}{7}=0,\ d=\frac{80}{7}$$

$$\frac{n}{7}=\frac{80}{7}$$

$n = 80$

18. [400]

$u = -100$cm

$$f=\frac{R}{2}=-100\text{cm}$$

after 10 sec $i = \frac{6}{6} = 1A$

$u = -80$m

As per mirrors formula

$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-100}-\frac{1}{-80}=\frac{1}{400}$$

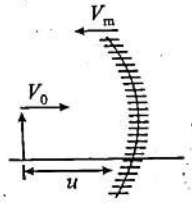
$\therefore v = 400$ cm

19. [3] We have, $u = -30$ cm, $f = -10$ cm

$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-10}-\frac{1}{-30}=\frac{1}{30}-\frac{1}{10}$$

$$=\frac{1-3}{30}=\frac{-1}{15}$$

So, $v = -15$



As, $\vec{V}_{I,M} = -\left(\frac{v}{u}\right)^2 \vec{V}_{O,M}$

$$\Rightarrow \vec{V}_I - \vec{V}_M = -\left(\frac{v}{u}\right)^2 (\vec{V}_o - \vec{V}_m)$$

$$\Rightarrow 0-\vec{V}_M = -\frac{1}{4}(15\hat{i}-\vec{V}_m)$$

$$\Rightarrow -\vec{V}_M = -\frac{15}{4}\hat{i}+\frac{1}{4}\vec{V}_M$$

$$\Rightarrow -\vec{V}_M = 3\hat{i}$$

20. (d) As height of image is less than height of object and has same orientation as that of object, so mirror must be convex.

@FAKE_CBSE_X @RAJEDUNET

11. (d) We know that, focus of a spherical convex mirror is in the same side of centre of curvature.

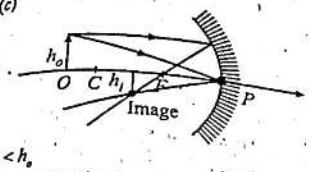
Therefore, $f = +\frac{1}{2}r$.

12. (c) Using Newton's formula,

$\Rightarrow (f+d_1)(f-d_2) = f^2$

$\Rightarrow f = \frac{d_1 d_2}{d_1 - d_2} \Rightarrow R = 2f = \frac{2d_1 d_2}{d_1 - d_2}$

13. (c)



$h_i < h_o$

Therefore, the image formed is real, inverted and diminished or unmagnified.

Hence, option (c) is correct answer

14. (d) At focus, magnification is ∞.

15. [1.00] Relation between object speed and image speed.

$V_i = -\left(\frac{v}{u}\right)^2 V_0 = -\left(\frac{10}{30}\right)^2 \times 9$

$= -1$ cm/s.

16. (b)

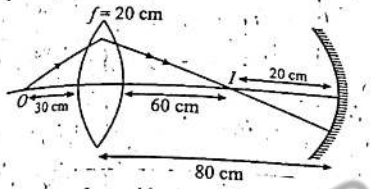


Image formed by lens

$\frac{1}{v} + \frac{1}{30} = \frac{1}{20}$

$\Rightarrow v = +60$ cm

If image position does not change even when mirror is removed it means image formed is at centre of curvature of the mirror.

Radius of curvature of mirror = 80 – 60 = 20 cm

$\Rightarrow f = 10$ cm

For virtual image, object is to be kept between focus and pole.

$\Rightarrow$ Maximum distance of object from spherical mirror for which virtual image is formed, is 10 cm.

27. (d) $m = \frac{f}{f-u}$, $5 = \frac{-40}{-40-u}$

$u = -32$ cm

28. (a) Given, $u = -1.9$ m $= -190$ cm

$f = 10$ cm.

For mirror

$\vec{V}_{I,M} = -m^2 \vec{V}_{O,M}$

$\vec{V}_{IM} \rightarrow$ Velocity of image w.r.t mirror

$\vec{V}_{OM} \rightarrow$ Velocity of object w.r.t mirror

$m \rightarrow$ magnification

Formula of magnification,

$m = \frac{f}{f-u}$

$= \frac{10}{10-(-190)}$

$= \frac{10}{200} = \frac{1}{20}$

$\left|\vec{V}_{IM}\right| = \left(\frac{1}{20}\right)^2 \left|\vec{V}_{OM}\right|$

$= \frac{1}{(20)^2} \times 40 = 0.1 m/s$

29. [31] Given: Height of column = 6 cm

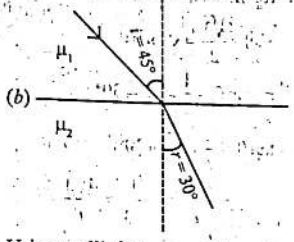
Apparent depth $h_{app} = \frac{h_1}{\mu_1} + \frac{h_2}{\mu_2}$

$= \frac{6}{3/2} + \frac{6}{8/5} = 4 + \frac{15}{4} = \frac{31}{4}$ cm

30. (b) From the formula $n = \frac{\text{real depth}}{\text{apparent depth}}$; $d_{app} = \frac{d_1}{n_1} + \frac{d_2}{n_2}$

$d_{app} = \frac{d}{2}\left[\frac{n_1 + n_2}{n_1 n_2}\right]$

31. (b)



Using snell's law,

$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}, \frac{\sin 45°}{\sin 30°} = \frac{\mu_2}{\mu_1}$

$\therefore$ Refractive Index(μ)

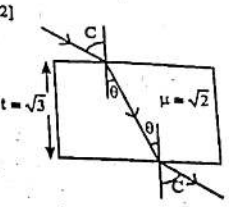
$\frac{\mu_1}{\mu_2} = \frac{1}{\sqrt{2}} \propto \frac{1}{\text{wavelength } (\lambda)}$

$\therefore \frac{\mu_1}{\mu_2} = \frac{\lambda_2}{\lambda_1} = \frac{1}{\sqrt{2}}$

$\lambda_2 = \frac{\lambda_1}{\sqrt{2}}$

Frequency will same in both medium.

32. [52]



$\sin C = \frac{1}{\sqrt{2}} \Rightarrow C = 45°$

Using Snell's law

$\sin C = \mu \sin\theta$

$\frac{1}{\sqrt{2}} = \sqrt{2}\sin\theta \Rightarrow \theta = 30°$

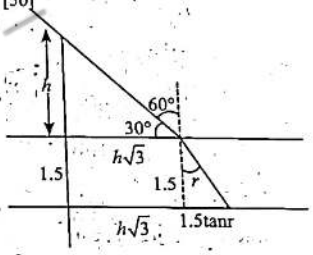
Lateral displacement x is given by

$x = t\sin(i-r)\sec r \Rightarrow$

$x = \sqrt{3}\sin(45° - 30°)\sec 30°$

$\Rightarrow x = \sqrt{3}(0.26)\left(\frac{2}{\sqrt{3}}\right) = 52 \times 10^{-2}$ cm

33. [50]



Applying Snell's law,

$1\sin 60° = \frac{4}{3}\sin r \Rightarrow \sin r$

$= \frac{3\sqrt{3}}{8} \Rightarrow \tan r = \frac{3\sqrt{3}}{\sqrt{37}}$

From the diagram

$h\sqrt{3} + 1.5\tan r = 2.15$

$h\sqrt{3} = 2.15 - 1.5 \times \frac{3\sqrt{3}}{\sqrt{37}}$

$h = \frac{2.15}{\sqrt{3}} - \frac{1.5 \times 3}{\sqrt{37}} = 0.502 \approx 0.50$ meter

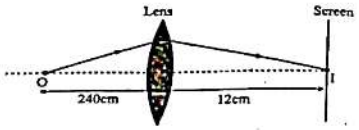
34. [3] $\frac{V_{bf}}{\mu_w} = \frac{-8}{\mu_w} + \frac{(-v)}{1}$

$\Rightarrow \frac{-12}{\frac{4}{3}} = \frac{-8}{\frac{4}{3}} + \frac{(-v)}{1}$

$\Rightarrow v = 3$ m/s

@TIME_CBSE_FORUM@RAJ_EWINET

35. (*b*)



Given, $u = -2.4\text{ m} = 240\text{ cm}$, $v = 12\text{ cm}$

using lens formula $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$\frac{1}{12}-\frac{1}{-240}=\frac{1}{f}\ \frac{1}{f}=\frac{210}{24}$ ...(i)

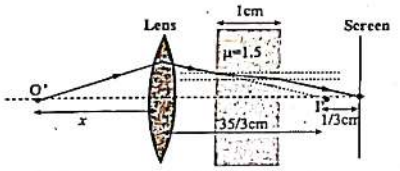
Shift produced by a glass slab put in between lens and screen

$d = t\left(1-\frac{1}{\mu}\right)=1\left(1-\frac{1}{1.5}\right)=\frac{1}{3}\text{cm}$

New image distance, $v = 12-\frac{1}{3}=\frac{35}{3}$

Now using lens formula, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$\Rightarrow \frac{3}{35}-\frac{1}{u}=\frac{1}{f}$ ...(ii)



From equation (i) and (ii)

$\frac{3}{35}-\frac{1}{u}=\frac{210}{24}$, $u = -560$ cm

Distance of object shifted,

$\Rightarrow |\Delta u| = 560 - 240 = 320\text{ cm} = 3.2\text{ m}$

36. (*a*) In a medium, speed of light,

$v=\frac{C}{\sqrt{\mu_r\varepsilon_r}}$

So, $v_2=\frac{3\times10^8}{\sqrt{1\times9}}=1\times10^8\ m/s$

37. (*a*) Since, $\mu=\frac{c}{V}$, therefore $\mu\propto\frac{1}{v}$

$\frac{m_A}{m_B}=\frac{v_B}{v_A}=\frac{1}{2}$

Let the thickness is d

Given: $t_1 - t_2 = 5\times10^{-10}$

$\frac{d}{v_B}-\frac{d}{v_A}=5\times10^{-10}$

$d=\frac{5\times10^{-10}\times v_A v_B}{v_A-v_B}$

As $v_A = 2v_B \Rightarrow d=\frac{5\times10^{-10}\times2v_A.v_B}{2v_A-v_B}$

$=5\times10^{-10}\times2V_B$

or $d=5\times10^{-10}\times v_A$

38. (*d*) From Snell's law

$\sin i\times1=\sin\frac{i}{2}\times\sqrt{2n}$

$2\sin\frac{i}{2}\cdot\cos\frac{i}{2}=\sin\frac{i}{2}\times\sqrt{2n}$

$\cos\frac{i}{2}=\sqrt{\frac{n}{2}}\Rightarrow i=2\cos^{-1}\left(\sqrt{\frac{n}{2}}\right)$

39. (*c*) $v_A - v_B = 2.6\times10^7$ m/s

$v=\frac{c}{\mu}$, $\Rightarrow v_B=\frac{3\times10^8}{1.47}=2.04\times10^8$

$=20.4\times10^7$ m/s

$\therefore v_A = (20.4+2.6)\times10^7 = 23\times10^7$ m/s

$\therefore \frac{\mu_B}{\mu_A}=\frac{v_A}{v_B}=\frac{23\times10^7}{20.4\times10^7}=1.13$

40. (*c*) Using snell's law -

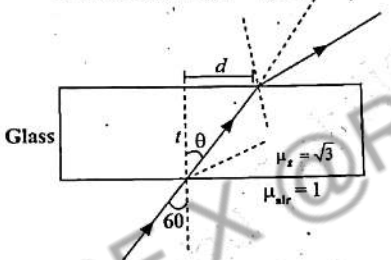
$\sin i=\mu\sin r$

$\Rightarrow \sin45°=\mu\sin30°\ (r=45°-15L=30°)$

$\mu=\frac{\sin45}{\sin30}=\frac{1}{\sqrt{2}}\times2=\sqrt{2}$

41. [12]

Given lateral shift, $d = 4\sqrt{3}$cm



Using snell's law,

$\mu_{air}\sin60°=\mu_0\sin\theta$

$\Rightarrow 1\times\frac{\sqrt{3}}{2}=\sqrt{3}\sin\theta$

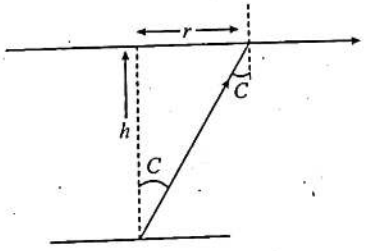
$\Rightarrow \sin\theta=\frac{1}{2}\Rightarrow\theta=30°$

$\tan\theta=\frac{d}{t}\Rightarrow\tan30°$

$=\frac{4\sqrt{3}}{t}\Rightarrow\frac{1}{\sqrt{3}}=\frac{4\sqrt{3}}{t}$

$\therefore t=4\sqrt{3}\times\sqrt{3}=12\text{cm}$

42. [9] Given, $h=\sqrt{7}m$, $\mu=4/3$



$\tan C=\frac{r}{h}$

$r = h\tan C$

$\sin C=\frac{1}{\mu}=\frac{3}{4}$, $\tan C=\frac{3}{\sqrt{7}}$

$r=\sqrt{7}\times\frac{3}{\sqrt{7}}=3$

Area of surface $= \pi r^2 = 9\pi\ m^2$

43. [15]

Incident vector makes angle i with normal z axis.

$\therefore \cos i=\frac{5}{\sqrt{48+27+25}}$

$\Rightarrow i = 60°$

Using Snell's law

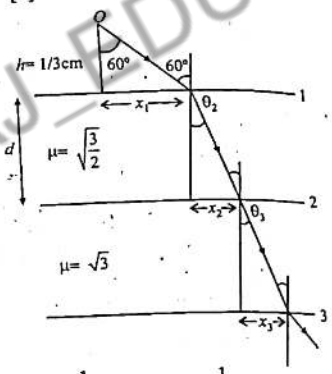
$\mu_1\sin i=\mu_2\sin r$

$\sin r=\frac{\sqrt{2}}{\sqrt{3}}\sin60°$

$\Rightarrow r = 45°$

Therefore, $i - r = 60° - 45° = 15°$

44. [4] As



$x_1=\frac{1}{3}\times\tan60°=\frac{1}{\sqrt{3}}\text{cm}$

At interface - 1

$1\sin60°=\sqrt{\frac{3}{2}}\sin\theta_2$

$\Rightarrow\theta_2=45°$

So, $x_2 = d\tan45°=\frac{\sqrt{3}-1}{2}$

At interface - 2

Again $\sqrt{\frac{3}{2}}\sin45°=\sqrt{3}\sin\theta_3$

$\Rightarrow\theta x_3=30°$

So, $x_3 = d\tan30°=\frac{\sqrt{3}-1}{2\sqrt{3}}$

So, $x_1+x_2+x_3=\frac{1}{\sqrt{3}}+\frac{\sqrt{3}-1}{2}\left(1+\frac{1}{\sqrt{3}}\right)$

$=$

$\frac{1}{\sqrt{3}}+\frac{(\sqrt{3}-1)(\sqrt{3}+1)}{2\sqrt{3}}=\frac{1}{\sqrt{3}}+\frac{1}{\sqrt{3}}=\frac{2}{\sqrt{3}}$

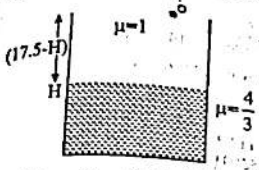
@FAKE_CBSE_X_@RAJ_EDUNET

So 1 unit shift light ray by $\frac{2}{\sqrt{3}}$, therefore

to shift light ray by $l=\frac{8}{\sqrt{3}}$, no. of units needed,

$$n=\frac{\frac{8}{\sqrt{3}}}{\frac{2}{\sqrt{3}}}=4$$

45. (*d*) Height of water observed by an observer which is outside the water



$$\Rightarrow \frac{H}{\mu_a}=\frac{H}{(4/3)}=\frac{3H}{4}$$

As $\frac{3H}{4}=17.5-H$, $\frac{7H}{4}=17.5$

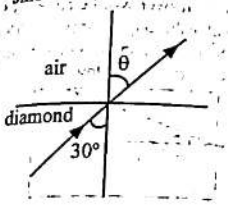
$7H=70, H=10$ cm

46. (*d*) From snell's law

$\mu_1 \sin 30^\circ=\mu_2 \sin\theta$

$\Rightarrow 2.42\times\frac{1}{2}=(1)\sin\theta$

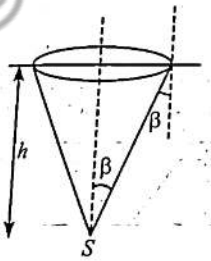
$\sin\theta=1.21>1$



Refraction is not possible

47. (*b*) Suppose the cone of light formed on the surface of water, as shown in the figure, β is the crtical angle

$\sin\beta=\frac{3}{4}, \cos\beta=\frac{\sqrt{7}}{4}$



We know, Solid angle

$d\Omega=2\pi R^2(1-\cos\beta)$

Percentage of light

$$=\frac{2\pi R^2(1-\cos\beta)}{4\pi R^2}\times 100$$

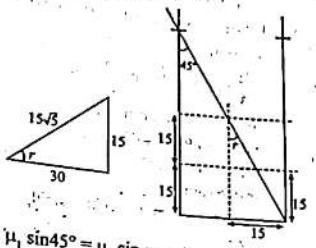
$$=\frac{1-\cos\beta}{2}\times 100=\left(\frac{4-\sqrt{7}}{8}\right)\times 100\approx 17\%$$

48. (c) Apparent depth of the inner surface of the bottom of the vessel, $d=\frac{h}{\sqrt{2}}+\frac{h}{2\sqrt{2}}$

$$\Rightarrow d=\frac{h}{\sqrt{2}}\times\frac{3}{2}=\frac{3\sqrt{2}h}{4}$$

49. [158]

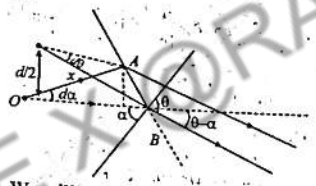
See the figure For *r*



$\mu_1 \sin 45^\circ=\mu_2 \sin r$

$$\Rightarrow \frac{1}{\sqrt{2}}=\frac{\mu}{\sqrt{5}} \quad \therefore \mu=\sqrt{\frac{5}{2}}=1.58\approx\frac{158}{100}$$

50. [2]



We will assume that observer sees the image of object through edge $\Rightarrow \alpha=45^\circ$

$$AB=\frac{12d\alpha}{\cos\alpha}=\frac{xd\theta}{\cos\theta}$$

By applying Snell's Law

$$\frac{4}{3}\sin\alpha=1\sin\theta$$

$$\frac{4}{3}\cos\alpha d\alpha=\cos\theta d\theta$$

$$\Rightarrow \frac{9}{\cos^2\alpha}=\frac{x}{\cos^2\theta}$$

$$1\sin\theta=\frac{4}{3}\sin\alpha$$

$$\Rightarrow \sin\theta=\frac{2\sqrt{2}}{3} \Rightarrow x=18\times\frac{1}{9}=2$$

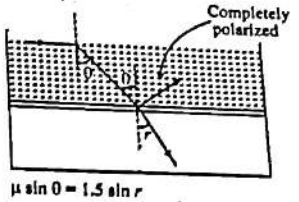
$$d=2x\sin(\theta-\alpha)$$

$$=4\times\frac{1}{\sqrt{2}}\left(\frac{2\sqrt{2}}{3}-\frac{1}{3}\right)$$

$$=\frac{8-2\sqrt{2}}{3}\approx 1.73\approx 2$$

51. (*b*) $\sin 90^\circ=\mu\sin\theta$

$$\Rightarrow \sin\theta=\frac{1}{\mu}$$



$\mu\sin\theta=1.5\sin r$

$\mu\sin\theta=1.5\cos\theta \quad (\theta+r=90^\circ)$

$$\Rightarrow \tan\theta=\frac{1.5}{\mu}$$

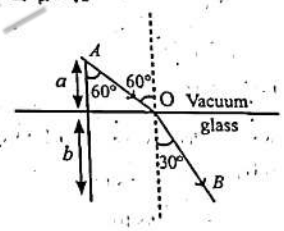
$$\sin\theta=\frac{3}{\sqrt{9+4\mu^2}}=\frac{1}{\mu}$$

$9\mu^2=9+4\mu^2 \Rightarrow \mu=\frac{3}{\sqrt{5}}$

52. (*d*) From Snell's law

$1\sin 60^\circ=\mu\sin 30^\circ$ [Refractive in day of vacuum is 1]

$\Rightarrow \mu=\sqrt{3}$



Optical path = AO + μ(OB)

$$=\frac{a}{\cos 60^\circ}+\sqrt{3}\frac{b}{\cos 30^\circ}$$

$=2a+2b$

Hence, option (*d*) is correct answer.

53. (2) Given, $i=\theta_c$

$$\Rightarrow i=\sin^{-1}\left(\frac{1}{\mu}\right)$$

$\Rightarrow i=45$

From snell's law

$1\sin 45^\circ=\sqrt{2}\sin r$

$\Rightarrow r=30^\circ$

Lateral displacement

$$\Delta t=\frac{t\sin(i-r)}{\cos r}$$

$$\Delta t=\frac{4\sqrt{3}\times\sin 15^\circ}{\cos 30^\circ}=2cm$$

@FAKE CBSE XII RAJ_ANUNET

54. (a) $\sin\theta_c = \frac{\mu_R}{\mu_d} = \frac{\mu_2}{\mu_1}$

The ratio of the refractive indices of first and second media

$\frac{\mu_2}{\mu_1} = \sin 45°$

$\Rightarrow \frac{1}{\sqrt{2}} = \frac{\mu_2}{\mu_1}$

$\Rightarrow \frac{\mu_1}{\mu_2} = \frac{\sqrt{2}}{1}$

55. (b) Critical angle, $\sin c = \frac{1}{\mu} = \frac{1}{\frac{c}{v}}$

$\Rightarrow V = C \sin c$

$= 3 \times 10^8 \times \sin 45°$

$= 3\times10^8 \times \frac{1}{\sqrt{2}} = 2.12 \times 10^8$ m/s

56. [5] $\because \mu = \frac{c}{V} = \frac{c}{0.2c}$

$\Rightarrow \mu = 5$

$\because \mu = \sqrt{\epsilon_r \mu_r}$

$\Rightarrow \epsilon_r' = \frac{\mu^2}{\mu_r}$

$\Rightarrow \frac{\epsilon_r}{\mu} = \frac{\mu}{\mu_r} = 5$

57. (d) We have given,

$v_A = 2 \times 10^{10}$ cm/s, $v_B = 1.5 \times 10^{10}$ cm/s

We know that, for total internal reflection,

$\frac{\sin\theta_C}{v_B} = \frac{\sin 90°}{v_A} \Rightarrow \sin\theta_C = \frac{v_B}{v_A} = \frac{1.5\times10^{10}}{2.0\times10^{10}} = \frac{3}{4}$

$\Rightarrow \theta_C = \sin^{-1}\left(\frac{3}{4}\right)$

According to question, we can write

$\theta > \theta_c = \sin^{-1}\left(\frac{3}{4}\right)$

58. (a) $\sin i_C = \frac{\mu_{rarer}}{\mu_{dener}} = \frac{\text{velocity of rarer}}{\text{velocity of denser}}$

(i_C is critical angle)

$\Rightarrow \sin i_C = \frac{1.5\times10^8}{2\times10^8} = \frac{3}{4}$

$\therefore \tan i_C = \frac{3}{\sqrt{7}} \quad \left[\because \tan\theta = \frac{\sin\theta}{\sqrt{1-\sin^2\theta}}\right]$

$\Rightarrow i_C = \tan^{-1}\left(\frac{3}{\sqrt{7}}\right)$

59. (d) Condition for total internal reflection,

$i > \theta_C$

$\Rightarrow \sin i > \sin\theta_C$

$\Rightarrow \sin i > \frac{\mu_R}{\mu_D}$ ...(i)

And $\mu = \sqrt{\mu_r \epsilon_r}$

$\frac{\mu_R}{\mu_D} = \frac{\sqrt{1\times1}}{\sqrt{4\times1}} = \frac{1}{2}$

From (i), $\sin i > \frac{1}{2} \Rightarrow i > 30°, i = 60°$

60. (d) In primary rainbow, red colour is at top and violet is at bottom. Intensity of secondary rainbow is less in comparison to primary rainbow.

61. (b) Applying snell's law on first surface

$1 \times \sin\theta$

$= \frac{4}{3} \times \sin\theta' \Rightarrow \sin\theta' = \frac{3}{4}\sin\theta$ ... (i)

For TIR on second surface

$\sin\theta'' > \sin\theta_c$ ($\theta' + \theta'' = 90$)

$\sin(90 - \theta') > \sin\theta_c$

$\cos\theta' > \sin\theta_c$

$\cos^2\theta' > \sin^2\theta_c \Rightarrow 1 - \sin^2\theta' > \sin^2\theta_c$

$1 - \left(\frac{3}{4}\sin\theta\right)^2 > \sin^2\theta_c$ (By equation (i))

$1 - \frac{9}{16}\sin^2\theta > \sin^2\theta_c \therefore \left[\sin\theta_c = \frac{1}{\mu} = \frac{3}{4}\right]$

$1 - \frac{9}{16}\sin^2\theta > \frac{9}{16} \Rightarrow 1 - \frac{9}{16} > \frac{9}{16}\sin^2\theta$

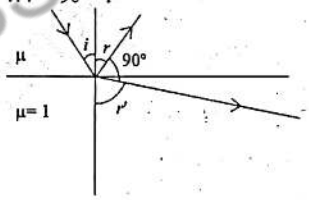
$\frac{7}{16} > \frac{9}{16}\sin^2\theta \Rightarrow \sin\theta < \frac{\sqrt{7}}{3}$

62. (d) $r + r' = 90°$

$\Rightarrow r' = 90° - r$

$\because$ *Law of refraction* $i = r$

$\therefore r' = 90° - i$



Snell's law:

$\mu \sin i = 1 \sin r' \Rightarrow \mu \sin i = \sin(90° - i)$

$\Rightarrow \tan i = \frac{1}{\mu} = \tan r$

Now critical angle:

$\mu \sin C = 1 \sin 90° = 1$

$\Rightarrow \sin C = \frac{1}{\mu} = \tan r$

$C = \sin^{-1}(\tan r)$

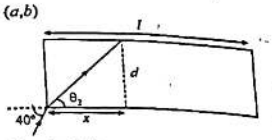
63. (a) Fact based

64. (b) $V = \frac{1}{\sqrt{\mu\varepsilon}}$, $n = \sqrt{\mu_r \varepsilon_r} = 2$

$\sin c = \frac{1}{2}$

$c = 30°$

65. (a,b)



Exact solution

by Snells' law $1.\sin 40° = (1.31)\sin\theta_2$

$\sin\theta_2 = \frac{0.64}{1.31} = \frac{64}{131} \approx 0.49$

Now $\tan\theta_2 = \frac{64}{\sqrt{(131)^2 - (64)^2}}$

$\frac{64}{\sqrt{13065}} \approx \frac{64}{114.3} \approx \frac{d}{x}$

Now no. of reflections $= \frac{2}{x}$

$= \frac{2\times64}{114.3\times20\times10^{-6}} = \frac{64\times10^5}{114.3}$

$\approx 55991 \approx 55000$

Approximate solution

By Snells' law $1.\sin 40° = (1.31)\sin\theta_2$

$\sin\theta_2 = \frac{0.64}{1.31} = \frac{64}{131} \approx 0.49$

If assume $\Rightarrow \theta_2 \approx 30°$

$\tan 30° = \frac{d}{x} \Rightarrow x = \sqrt{3}d$

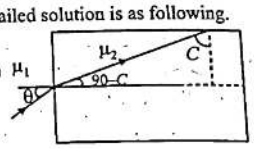
Now number of reflections

$= \frac{1}{\sqrt{3}d} = \frac{2}{\sqrt{3}\times20\times10^{-6}} = \frac{10^5}{\sqrt{3}}$

$\approx 57735 \approx 57000$

Note : If we approximate the angle θ_2 as 30° initially then answer will be closer to 57000. But if we solve thoroughly, answer will be close to 55000. So both the answers must be awarded. Detailed solution is as following.

66. (b) μ_1



$\sin c = \frac{\mu_1}{\mu_2}$, $\mu_1 \sin\theta = \mu_2 \sin(90° - C) = \mu_2 \cos C$

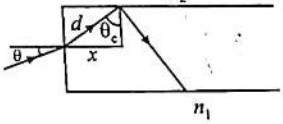
$\sin\theta = \frac{\mu_2\sqrt{1 - \frac{\mu_1^2}{\mu_2^2}}}{\mu_1}$, $\theta = \sin^{-1}\sqrt{\frac{\mu_2^2 - \mu_1^2}{\mu_1^2}}$

For TIR

$\theta < \sin^{-1}\sqrt{\frac{\mu_2^2}{\mu_1^2} - 1}$

67. [50.00]

For maximum time the ray of light must undergo *TIR* at all surfaces at minimum angle *i.e.*, θ_c



For *TIR* $n_1 \sin\theta_C = n_2$

$\sin\theta_C = \frac{1.44}{1.5}$

@FAKE_CBSE_X @RAJEDUNET

As above, $\sin\theta_c = \frac{x}{d}$ $d = \frac{x}{\sin\theta_c}$

Similarly, $D = \frac{L}{\sin\theta_c}$

Where L = length of tube

D = length of path of light

Time taken by light

$t = \frac{D}{c} = \frac{L/\sin\theta_c}{3\times10^8}$ $t = 50\times10^{-9}$ s

68. (d) Refractive index of a prism is given by,

$$\mu = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\frac{A}{2}}$$

$$\frac{\cos\frac{A}{2}}{\sin\frac{A}{2}} = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\frac{A}{2}}$$

$$\sin\left(\frac{\pi}{2}-\frac{A}{2}\right) = \sin\left(\frac{A+\delta_m}{2}\right)$$

$$\frac{\pi}{2}-\frac{A}{2} = \frac{A}{2}+\frac{\delta m}{2}$$

$$\delta_m = \pi - 2A$$

69. (a) $\cot\frac{A}{2} = \frac{\sin\left(\frac{A+\delta_{min}}{2}\right)}{\sin\frac{A}{2}}$

$$\Rightarrow \cos\frac{A}{2} = \sin\left(\frac{A+\delta_{min}}{2}\right)$$

$$\frac{A+\delta_{min}}{2} = \frac{\pi}{2}-\frac{A}{2}$$

$$\delta_{min} = \pi - 2A$$

70. (a) Wavelength orders for the different colours As $\lambda_{red} > \lambda_{yellow} > \lambda_{violet}$

Light ray with longer wavelength bends less.

Also, refractive index is medium dependent

71. (2) For angle of minimum deviation, $i = e$

and $r_1 = r_2 = \frac{A}{2}$

Given, $\frac{\delta_{min}}{A} = 1$

$$\therefore \frac{2i-A}{A} = 1$$

$\therefore i = A$ ...(i)

For snell's law

$$\sin i = \mu\sin\left(\frac{A}{2}\right)$$

From (i)

$$\sin A = \mu\sin\left(\frac{A}{2}\right)$$

$$2\sin\frac{A}{2}\cos\frac{A}{2} = \sqrt{3}\sin\left(\frac{A}{2}\right)$$

$$\cos\left(\frac{A}{2}\right) = \frac{\sqrt{3}}{2} \Rightarrow \frac{A}{2} = 30°$$

$\therefore A = 60°$

72. (d) For no deviation $\delta_1 = \delta_2$

$\Rightarrow 6°(1.54-1) = A(1.72-1)$

$\Rightarrow A = \frac{6°\times0.54}{0.72} = \frac{18°}{4} = 4.5°$

73. [30]

As $\mu = \frac{\sin\left(\frac{\delta_m+A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

$$\sqrt{2} = \frac{\sin\frac{(\delta_m+60°)}{2}}{\sin\left(\frac{60°}{2}\right)} \quad \frac{\sin\left(\frac{\delta_m+60°}{2}\right)}{\frac{1}{2}}$$

$$\Rightarrow \frac{1}{\sqrt{2}} = \sin\left(\frac{\delta_m+60°}{2}\right) \Rightarrow \sin 45°$$

$$= \sin\left(\frac{\delta_m+60°}{2}\right)$$

$$\Rightarrow \frac{\delta_m+60°}{2} = 45° \quad \Rightarrow \delta_m = 30°$$

74. (a, c, d)

For blue light, $\mu_B = \sqrt{3}$

$$i = \theta_B = \tan^{-1}(\mu_B) = \tan^{-1}(\sqrt{3})$$

$$= \tan^{-1}(\tan 60°) = 60°$$

Applying Snell's law, on first interface

$1\sin 60° = \sqrt{3}\sin r_1 \Rightarrow r_1 = 30°$

$\because r_1 + r_2 = A \Rightarrow r_2 = A - 30°$

Since, $\delta = (i+e) - A$

$\therefore 60° = 60° + e - A \Rightarrow e = A$

Applying Snell's law on second interface,

$\sqrt{3}\sin r_2 = 1\sin e$, $\sqrt{3}\sin(A-30) = \sin A$

On solving, we get

$A = 60°$

$\therefore e = 60°$

For red light, prism formula of refractive index.

$$\mu = \frac{\sin\left(\frac{A+\delta_{min}}{2}\right)}{\sin\frac{A}{2}}$$

$$= \frac{\sin\left(\frac{60°+30°}{2}\right)}{\sin\left(\frac{60°}{2}\right)} = \sqrt{2}$$

75. (a) Given,

$\mu = \cot\left(\frac{A}{2}\right)$, refracting angle = A

At minimum deviation, $r = \frac{A}{2}$

Formula of refractive index of prism,

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

$$\cot\frac{A}{2}\cdot\sin\frac{A}{2} = \sin\left(\frac{A+\delta_m}{2}\right)$$

$$\cot\frac{A}{2} = \sin\left(\frac{A+\delta_m}{2}\right)$$

$$\sin\left(\frac{\pi}{2}-\frac{A}{2}\right) = \sin\left(\frac{A+\delta_m}{2}\right)$$

$\pi - A = A = \delta_m$, $\delta_m = \pi - 2A$

76. (d) When electric field vector is completely removed and incident on Brewster's angle then only refraction takes place because direction of polarization is not mentioned.

77. [27]

Applying Snell's law

$78.....5\times\sin 60° = n\times\sin 90°$

$$\Rightarrow 1.5\times\frac{\sqrt{3}}{2} = n = \frac{\sqrt{x}}{4} \Rightarrow x = 27$$

78. [4] $\delta = \delta_1 - \delta_2 = A(\mu_y - 1) - A'(\mu'_y - 1)$

$= 6(1.5-1) - 5(1.55-1)$

$= \frac{1}{4}$

$\therefore x = 4$

79. [12]

Net deviation $\delta_{net} = (\mu_1 - 1)A_1 - (\mu_2 - 1)A_2$

$\Rightarrow 0.5A_1 - 0.6A_2 = 2°$ ... (i)

For zero dispersion,

$\omega_1(\mu_1 - A)A_1 = \omega_2(\mu_2 - 1)A_2$

$\Rightarrow 0.02(0.5)A_1 = 0.03(0.6)A_2$

$\Rightarrow 10A_1 = 18A_2$ ... (ii)

From equation (i) and (ii)

$$\frac{A_1}{2} - \frac{A_1}{3} = 2°$$

$\therefore A_1 = 12°$

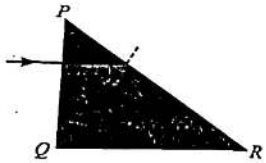
80. (a) For light ray to come out from face PR of prism, angle of incidence must be greater than critical angle.

$\therefore \theta_C > i = \theta \Rightarrow \sin\theta_c > \sin\theta$

$$\Rightarrow \frac{1}{\mu} > \sin\theta \quad \left[\because \sin\theta_C = \frac{1}{\mu}\right]$$

$$\Rightarrow \mu < \frac{1}{\sin\theta}$$

@FAKE_CBSE_T_@RAJEEV_NET



If the value of θ is 45°, we get $\mu < 1.414$, then only red colour light ray will come out from face *PR* of prism.

81. (*a*) Given, $\delta_m = A$

Prism formula, $\mu = \dfrac{\sin\left(\dfrac{(A+\delta_m)}{2}\right)}{\sin(A/2)}$

$$\mu = \frac{\sin A}{\sin\left(\frac{A}{2}\right)} = \frac{2\sin\left(\frac{A}{2}\right)\cos\left(\frac{A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\mu = 2\cos\left(\frac{A}{2}\right) \Rightarrow \frac{\mu}{2} = \cos\frac{A}{2}$$

$$A = 2\cos^{-1}\left(\frac{\mu}{2}\right)$$

82. (*b*) The angle of deviation trough a prism is minimum when

(i) Incident ray and emergent ray are symmetric to prism

(ii) The refracted ray inside the prism becomes paralles to its base.

(iii) Angle of incidence is equal to that of the angle of emergence.

83. (*b*) Angle of deviation $\delta = i + e - A$

δ_{min} for $i = e$

84. [600]

Since, light rays travel undeviated therefore, the refractive index of the medium would not change for any value of angle of incidence.

So, $n_1 = n_2$

$$\Rightarrow 1.2 + \frac{10.8\times10^{-14}}{\lambda_0^2} = 1.45 + \frac{1.8\times10^{-14}}{\lambda_0^2}$$

$$\Rightarrow \lambda = 600 \text{ nm}$$

85. [60]

At minimum deviation,

$$r_1 = r_2 = \frac{A}{2}$$

Using shell's law,

$$\mu_a \sin i = \mu_p \sin r_1$$

$$1.\sin A = \sqrt{3}\sin\frac{A}{2}$$

$$2\sin\frac{A}{2}\cos\frac{A}{2} = \sqrt{3}\sin\frac{A}{2}$$

$$2\cos\frac{A}{2} = \sqrt{3} \Rightarrow A = 60°$$

86. [5]

87. [05]

$\delta_{min} = (\mu - 1)A$

$$\Rightarrow \frac{N}{10} = (1.5-1)1 \Rightarrow N = 5$$

88. (*a*) Prism formula $D_m = S_m = (n-1)A$ (for thin prism)

So, answer is (*A*)

89. (*c*) For minimum deviation $i = e$

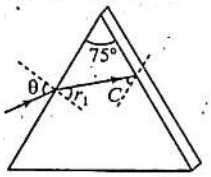
$$r_1 = r_2 = \frac{A}{2} = 30°$$

by Snell's law $1 \times \sin i = \sqrt{3} \times \frac{1}{2} = \frac{\sqrt{3}}{2}$

$i = 60°$

90. [1.50]

At θ = 60° ray incidents at critical angle at second surface



So, $1 \times \sin 60° = \sqrt{3}\ \sin r_1$

$$\frac{\sqrt{3}}{2} = \sqrt{3}\ \sin r_1$$

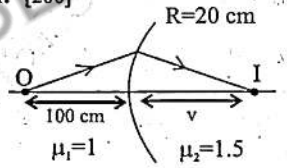
$r_1 = 30°$

$r_2 = 45° = C \quad (\because r_1 + r_2 = A)$

Aslo, $\sqrt{3}\ \sin 45° = n \sin 90°$

$$n = \sqrt{\frac{3}{2}} \Rightarrow n^2 = \frac{3}{2}$$

91. [200]



Using the formula,

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1.5}{v} - \frac{1}{-100} = \frac{1.5-1}{20}$$

$v = 100$ cm

Image distance from object = 100+100 = 200 cm

92. (*b*) $\mu = \dfrac{\text{real depth}}{\text{Apparent depth}}$

$$d_{apparent} = \frac{d_{actual}}{\mu_{rel}}$$

Let the real depth be x when riewed from one side.

$$\mu = \frac{x}{12} \Rightarrow x = 12\mu$$

Real depth from other side become 24 – x

$$\mu = \frac{24-x}{4} = \frac{24-12\mu}{4}$$

On solving we get $\mu = 1.5$

93. [120] For the plano concave lens

$$\frac{1}{f_1} = (1.75-1)\left(-\frac{1}{30}\right)$$

$$\Rightarrow f_1 = -40\,cm$$

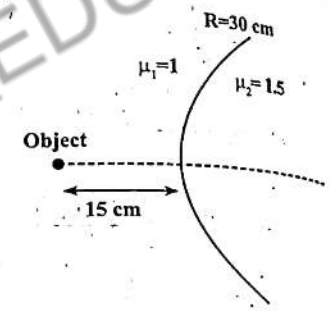
For the plano convex lens,

$$\frac{1}{f_2} = (1.75-1)\left(\frac{1}{30}\right) \Rightarrow f_2 = 40\,cm$$

Image from lens L_1 will be virtual and to the left of L_1 at focal length 40 cm. So the object for lens L_2 will be 80 cm from L_2 which is equal to 2*f*. Final image is formed at 80 *cm* from lens L_2 on the right side of the lens.

$$\Rightarrow x = 120$$

94. [30]



$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1.5}{v} - \frac{1}{(-15)} = \frac{1.5-1}{30}$$

$$\frac{1.5}{v} + \frac{1}{15} = \frac{1}{60} \Rightarrow v = -30 \text{ cm}$$

95. [225]

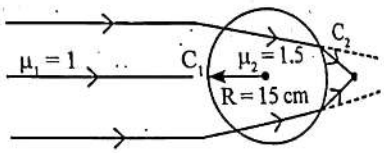
It is given,

$u = \infty$ [$\because$ object is at infinity].

$\mu_1 = 1$, $R = -15$cm, $\mu_2 = 1.5$

we have to find distance from center of globe at which the beam of light can converge

$$\therefore \frac{-\mu_1}{u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R}$$



$$\Rightarrow \frac{-1}{\infty} + \frac{1.5}{v} = \frac{1.5-1}{15}$$

@RAJ_CBSE_KOTA_RAJ_EDUNEXT

solving we get $\mu = 1.5$

] For the plano concave lens

$(1.75-1)\left(\frac{-1}{30}\right)$

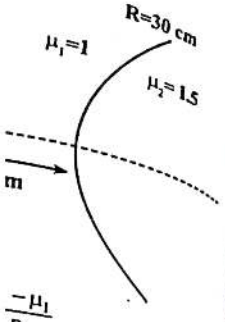
$= -40\,cm$

ne plano convex lens,

$(1.75-1)\left(\frac{1}{30}\right) \Rightarrow f_2 = 40\,cm$

from lens L_1 will be virtual and eft of L_1 at focal length 40 cm. So ect for lens L_2 will be 80 cm from h is equal to $2f$. Final image is at 80 cm from lens L_2 on the right ne lens.

:0



$\frac{-\mu_1}{R}$

$\frac{1.5-1}{30}$

$\Rightarrow v = -30\,cm$

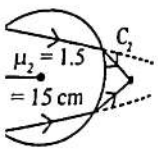
is at infinity].

$, \mu_2 = 1.5$

distance from centre

the beam of light can

$\frac{-\mu_1}{?}$



$\Rightarrow \frac{1.5}{v} = \frac{0.5}{15}$

$\therefore v = 5 < 45cm$

Now for Refraction through C_2

$u = +15$ cm, $\mu_1 = 1.5$, $\mu_2 = 1$, $R = -15$

We have to find v

$\frac{-\mu_1}{u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R}$

$\Rightarrow \frac{-1.5}{15} + \frac{1}{v} = \frac{1-1.5}{-15}$

$\Rightarrow \frac{-1}{10} + \frac{1}{v} = \frac{1}{30}$

$\frac{1}{v} = \frac{1}{30} + \frac{1}{10} = \frac{4}{10}$

$v = \frac{30}{4} = +7.5\,cm$

Distance from center = 15 + 7.5

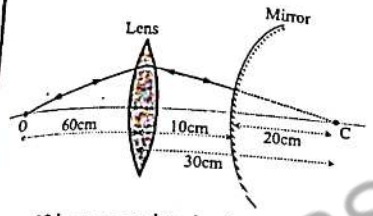
= 22.5 cm = 225mm

96. [10] For lens, apply lens formula,

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}, \quad \frac{1}{20} = \frac{1}{v} - \frac{1}{-60}$

$\Rightarrow \frac{1}{v} = \frac{1}{20} - \frac{1}{60} \Rightarrow \frac{1}{v} = \frac{3-1}{60} = \frac{1}{30}$

$\Rightarrow v = 30$ cm



If image need to be formed at object itself then light ray should retrace its path. Therefore after refraction at lens, it must strikes perpendicularly to the mirror. Radius of curvature of mirror $R = 20$ cm

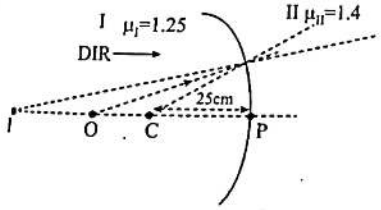
$\therefore$ focal length, $f = R/2 = 20/2 = 10$ cm

97. (c) $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

$\Rightarrow \frac{1.4}{v} - \frac{1.25}{-40} = \frac{1.4-1.25}{-25}$

$\Rightarrow -\frac{1.4}{v} = \frac{0.15}{25} + \frac{1.25}{40} = \frac{7.45}{200}$

$\Rightarrow v = -\frac{200 \times 1.4}{7.45} = -37.58\text{cm}$



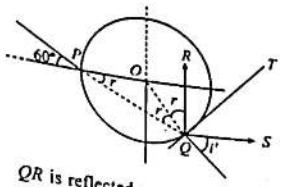
98. [30] We know that formula,

$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

$\mu_1 = 1, \mu_2 = 1.5$

$\frac{1.5}{+10} - \frac{1}{-15} = \frac{1.5-1}{+R}, \quad R = \frac{30}{13}\text{m}$

99. [90]



QR is reflected ray and QS is refracted ray. QT is tangent and OQ is normal.

Now, $\mu \times \sin 60° = \sqrt{3}\ \sin r$

$\Rightarrow \frac{\sqrt{3}}{2} = \sqrt{3}\ \sin r \Rightarrow \sin r = \frac{1}{2} \ \therefore r = 30°$

Yet again $\sqrt{3}\ \sin r = \sin i' \ \therefore i' = 60°$

$\therefore$ Angle between QR and QS

$\Rightarrow (\angle RQS) = 90°$

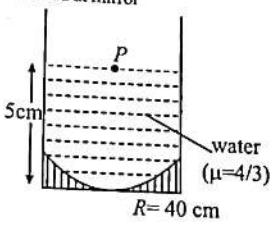
100. (d) $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

$\frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R} + \frac{\mu_1}{u}$

$\frac{1.34}{v} = \frac{1.34-1}{7.8} + \frac{1}{-\infty}$

$v = 3.074\text{ cm} \approx 3.1\text{ cm}$

101. (a) Light incident from particle P will be reflected at mirror



$u = -5\text{cm}, \ f = -\frac{R}{2} = -20\text{ cm}$

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$v_1 = +\frac{20}{3}\text{cm}$

This image will act as object for light getting refracted at water surface

So, object distance $d = 5 + \frac{20}{3} = \frac{35}{3}\text{cm}$ below water surface.

After refraction, final image is at

$d' = d\left(\frac{\mu_2}{\mu_1}\right) = \left(\frac{35}{3}\right)\left(\frac{1}{4/3}\right)$

$= \frac{35}{4} = 8.75\text{ cm} = 8.8\text{ cm}$

102. (d) For 1st lens

$\frac{1}{f_1} = \left(\frac{\mu_1 - 1}{1}\right)\left(\frac{1}{\infty} - \frac{1}{-R}\right) = \frac{\mu_1 - 1}{R}$

for 2nd lens

$\frac{1}{f_2} = \left(\frac{\mu_2 - 1}{1}\right)\left(\frac{1}{-R} - 0\right) = -\frac{\mu_2 - 1}{R}$

$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2}$

$\frac{1}{f_{eq}} = \frac{\mu_1 - 1}{R} - \frac{\mu_2 - 1}{R} = \frac{\mu_1 - \mu_2}{R}$

$\Rightarrow f_{eq} = \frac{R}{\mu_1 - \mu_2}$

103. (c,d)

$H_1 = \frac{2H}{3} = \frac{2}{3} \times \frac{3}{10} = \frac{1}{5}m$

$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

for 2nd

$\frac{1}{v_2} - \frac{1.5}{-0.3} = \frac{1-1.5}{-3}, \ \frac{1}{v_2} + 5 = \frac{1}{6}$

$\frac{1}{v_2} = \frac{1}{6} - 5 = \frac{-29}{6} \Rightarrow v_2 = -\frac{5}{29}$

$H_2 = \frac{6}{29} \Rightarrow H_2 > H_1$

For 3rd

$\frac{1}{v_3} - \frac{1.5}{-0.3} = \frac{1-1.5}{3}, \ \frac{1}{v_3} + 5 = -\frac{1}{6}$

$\frac{1}{v_3} = -\frac{1}{6} - 5 = -\frac{31}{6}$

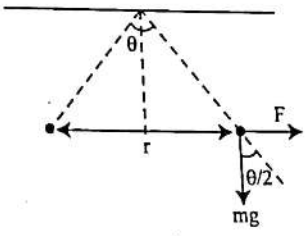
$v_3 = -\frac{6}{31}, H_3 = \frac{6}{31}$

$H_3 < H_1 < H_2$ and $(H_2 - H_3)$

So $= \frac{6}{29} - \frac{6}{31} = 0.68\text{ cm}$

104. [3] In air,

$\tan\frac{\theta}{2} = \frac{F}{mg} = \frac{q^2}{4\pi\varepsilon_0 r^2 mg} \quad ...(i)$



@FAKE_JEE_SEEK@RAJ_EDUNET

In water,

$$\tan\frac{\theta}{2}=\frac{F'}{mg'}=\frac{q^2}{4\pi\varepsilon_0\varepsilon_r r^2 mg_{eff}} \quad ...(ii)$$

Equating, both equations

$$\Rightarrow \varepsilon_0 g=\varepsilon_0\varepsilon_r g\left[1-\frac{1}{1.5}\right]$$

$$\Rightarrow \varepsilon_r=3$$

105. [10] From equation, $\frac{v}{u}=-2$

$v=-2u$ ...(i)

$v-u=45$ ...(ii)

After solving equation (i) and (ii) we get,

$\Rightarrow u=-15$ cm

$v=30$ cm

Now,

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}.$$

$f=+10$ cm

106. (20) $\frac{1}{f+20}-\frac{1}{-(f+20)}=\frac{1}{f}$

$$\frac{2}{f+20}=\frac{1}{f}\Rightarrow f=20 \text{ cm}$$

Or $x_1x_2=f^2$ gives $f=20$ cm

107. (*b*) Given $\mu_1=1.5$

$\mu_1=1.6$

$f_a=20$ cm

focal length when immersed in a liquid

As $\frac{f_m}{f_a}=\frac{(\mu_1-1)\mu_m}{(\mu_1-\mu_m)}$

$$\frac{f_m}{20}=\frac{(1.5-1)1.6}{(1.5-1.6)}$$

$f_m=-160$ cm

108. (*a*) As $P_{eq}=\Sigma P_i$

[beccuse all lenses are identical]

$\therefore 5P=25D$

$\Rightarrow P=5D$

$\Rightarrow \frac{1}{f}=5\Rightarrow f=\frac{1}{5}m=20cm$

109. (*c*) $\frac{1}{+20}=\left(\frac{\mu}{1}-1\right)\left(\frac{1}{+15}-\frac{1}{(-30)}\right)$

$$\Rightarrow \frac{1}{20}=(\mu-1)\left(\frac{3}{30}\right)$$

$$\Rightarrow \mu-1=\frac{1}{2}\Rightarrow \mu=1.5$$

110. (*a*) For lens 1 : $f_1=10, u=-30, v=?$

Using, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$$v=\frac{uf}{u+f}=\frac{-30\times10}{-30+10}=15$$

For lens 2 : $f_1=-10, u=10, v=?$

$$v=\frac{uf}{u+f}=\frac{10\times-10}{10-10}=\infty$$

For lens 3 : $f=30, u=-\infty, v=?$

So v will be 30.

111. (*a*) According to lens formula,

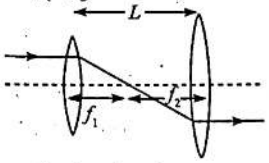
$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{v}-\frac{1}{-2f}=\frac{1}{-f}\Rightarrow v=-2f$$

$\frac{1}{v}=\frac{1}{u}+\frac{1}{f}\Rightarrow$ Virtual image of Real object for concave lens.

Statement II is correct for real object.

112. (c) Paraxial parallel rays pass through focus and ray from focus of convex lens will become parallel.

$L=f_1+f_2=25$ cm



113. (*a*) $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

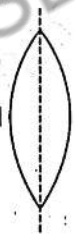
$$P=2D=2\text{m}^{-1}\Rightarrow\frac{1}{f}=\frac{2}{100}\text{cm}^{-1}$$

$$\frac{1}{V}-\left(-\frac{1}{25}\right)=\frac{2}{100}\Rightarrow\frac{1}{V}=\frac{1}{50}-\frac{1}{25}$$

$\Rightarrow V=-50$cm

114. (*b*) Based on fact.

115. [5]



Let power of each part is P_1, then

$$\Rightarrow\frac{1}{f}=P_1+P_1$$

$$\therefore P_1=\frac{1}{2f}$$

$$=\frac{1}{2\times0.1}=5D$$

116. [4] lens Maker formula

$$P=\frac{1}{f}=(h_g-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$=(1.8-1)\left(\frac{1}{20}+\frac{1}{20}\right)$$

$$P'=\frac{1}{f'}=\left(\frac{h_g}{h_w}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$=\left(\frac{1.8}{1.5}-1\right)\left(\frac{1}{20}+\frac{1}{20}\right)$$

$$\therefore \frac{P}{P'}=\frac{0.8}{1.2-1}=4$$

117. [30]

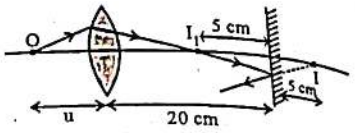


Image distance,

$v=20-5$

$=15$ cm

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f},\ \frac{1}{15}-\frac{1}{-u}=\frac{1}{10}$$

$$\Rightarrow\frac{1}{u}=\frac{1}{10}-\frac{1}{15}$$

$\Rightarrow u=30$cm.

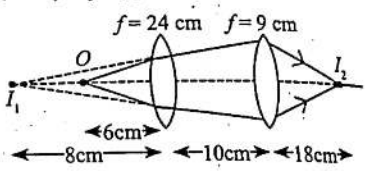
118. [34]

For L_1 : $\frac{1}{v}-\frac{1}{-6}=\frac{1}{24}$

$$\frac{1}{v}=\frac{1}{24}-\frac{1}{6}\Rightarrow v=-8\text{cm}$$

For L_2 : $\frac{1}{v}-\frac{1}{(-8-10)}=\frac{1}{9}$

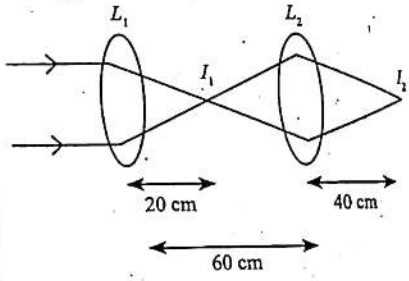
$$\frac{1}{v}=\frac{1}{9}-\frac{1}{18}\Rightarrow v=18$$



So $OI_2=6+10+18=34$ cm

119. [100] $f_1=20$ cm

$f_2=20$ cm



For L_1 Apply lens formula

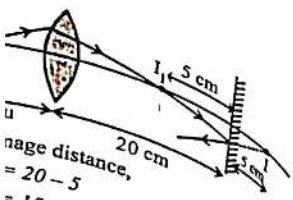
$$\frac{1}{v}-\frac{1}{\infty}=\frac{1}{f_1}$$

$\therefore v=f=20$ cm

@FAKE_CBSE_@RAJ_EDUNET

$\therefore \frac{P}{P'} = \frac{0.8}{1.2-1} = 4$

[30]



nage distance,
$= 20 - 5$
$= 15\ cm$

$\frac{1}{u} = \frac{1}{f}$, $\frac{1}{15} - \frac{1}{-u} = \frac{1}{10}$

$= \frac{1}{10} - \frac{1}{15}$

$= 30cm.$

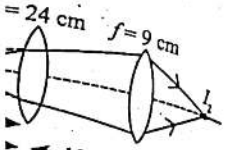
$\frac{1}{\nu} - \frac{1}{-6} = \frac{1}{24}$

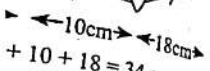
$\frac{1}{6} \Rightarrow \nu = -8cm$

$\frac{1}{\nu} - \frac{1}{(-8-10)} = \frac{1}{9}$

$\frac{1}{18} \Rightarrow \nu = 18$

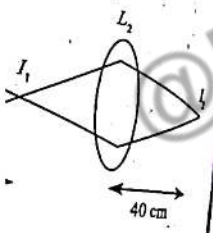
$= 24$ cm





$+ 10 + 18 = 34$ cm

'0 cm



0 cm

ns formula

For L_2, I_1 is object and I_2 is image

$\therefore u = -40$ cm

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_2}$, $\frac{1}{v} - \frac{1}{(-40)} = \frac{1}{20}$

$\frac{1}{V} = \frac{1}{20} - \frac{1}{40} = \frac{6-3}{120}$

$\frac{1}{V} = \frac{3}{120} = \frac{1}{40}$

$\therefore v = 40$ cm.

Therefore, total distance $= 60 + 40 = 100$ cm

120. [54]

$\because \frac{1}{f_{air}} = (\mu_g - 1)\left(\frac{2}{R}\right)$, $\frac{1}{f_{air}} = \frac{1}{R}$

and

$\therefore \frac{1}{f_{H_2O}} = \left(\frac{\mu_g}{\mu_{H_2O}} - 1\right)\left(\frac{2}{R}\right)$

$= \frac{1}{8}\left(\frac{2}{R}\right)$

$= \frac{1}{(4f_{air})}$

Therefore, $f_{H_2O} = 4f_{air} = 72cm$

So change in focal length $= 72 - 18 = 54cm$

121. (1) Given, $u = 10 \pm 0.1$ cm, $\Rightarrow v = 20 \pm 0.2$ cm

Lens Formula

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$\frac{1}{20} + \frac{1}{10} = \frac{1}{f} \Rightarrow \frac{1}{f} = \frac{3}{20} \Rightarrow f = \frac{20}{3}$ cm

$\Rightarrow \frac{1}{v^2}dv + \frac{1}{u^2}du = -\frac{1}{f^2}df$

$\Rightarrow \frac{1}{(20)^2}(0.2) + \frac{1}{(10)^2}(0.1) = \frac{9}{400}df$

$df = \frac{1}{9}\left(\frac{400}{400} \times 0.2 + \frac{400}{100} \times 0.1\right)$

$df = \frac{0.6}{9}$

$\frac{df}{f} = \frac{0.6}{9} \times \frac{3}{20} = \frac{1}{100}$

% error $= 1\%$

122. (a) $R_1 = R, R_2 = -R$

$P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R} - \left(\frac{1}{-R}\right)\right)$

$P = \frac{(\mu - 1)2}{R}$

For lens – 1,

$R_1 = R, R_2 = -R$

$P_1 = \frac{1}{f'} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$P_1 = \frac{(\mu - 1) \times 2}{R} = P$

For lens – 2

$R_1 = R, R_2 = \infty$

$P_2 = \frac{1}{f''} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right)$

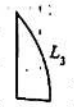
$P_2 = \frac{P}{2}$

For lens – 3

$R_1 = \infty, R_2 = -R$

$P_3 = \frac{1}{f'''} = (\mu - 1)\left(\frac{1}{\infty} - \left(-\frac{1}{R}\right)\right)$

$P_3 = \frac{\mu - 1}{R} = \frac{P}{2}$



123. (b) Given: Power of a lens, $P = 1.25\ m^{-1}$

$\mu_{lens} = 1.5, r_1 = 20cm, r_2 = 40cm$.

As, $P = \frac{1}{f} = 1.25$

$f = \frac{1}{1.25} \times 100 = \frac{4}{5} \times 100 = 80cm$

As, $\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$\Rightarrow 1/80 = \left(\frac{1.5}{\mu_1} - 1\right)\left(\frac{1}{20} + \frac{1}{40}\right)$

$\Rightarrow \mu_1 = \frac{9}{7}$

124. [10]

Lens maker formula

$\frac{1}{f_l} = (m_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

For the lens having refractive index; $\mu_g = 1.5$,

$\frac{1}{f_g} = (1.5 - 1)\left(-\frac{1}{R} - \frac{1}{R}\right)$

$\frac{1}{15} = 0.5 \times \left(-\frac{2}{R}\right)$

$R = -15$ cm $= 15$ cm

For the lens made of liquid

$\frac{1}{f_\ell} = (1.25 - 1)\left(-\frac{2}{R}\right) = \frac{0.5}{R}$

$\frac{1}{f_\ell} = \frac{0.5}{15} = \frac{1}{30} \Rightarrow f_\ell = -30$

Now, equivalent focal length

$\frac{1}{f_{eq}} = \frac{2}{f_g} + \frac{1}{f_\ell} = \frac{2}{15} - \frac{1}{30} = \frac{3}{30}$

$\because f_{eq} = 10$ cm

125. [10]

For point B, $\frac{1}{v} = 0, \frac{1}{u} = -0.10cm^{-1}$

$\therefore u = -10cm, v = \infty$

From lens formula

$f = 10cm$

From lens marker formula

$\frac{1}{10} = (1.5 - 1)\left(\frac{2}{R}\right) \Rightarrow \frac{1}{R} = \frac{1}{10}$

$R = 10cm$

126. [15]

As, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v'+f} - \frac{1}{u'-f} = \frac{1}{f}$

Also, $\mu'v' = 225$

Using Newton's formula, $\mu'v' = f^2$

$\Rightarrow f = 15$cm

127. (c) Refractive index of the material,

$\mu_g = \frac{c}{v_m} = \frac{3 \times 10^8}{2 \times 10^8} = 1.5$

Here MN = 3mm = 0.3 cm,

AN = BN = 3 cm

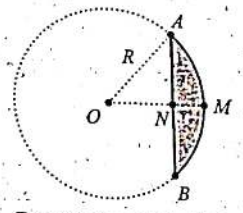
For right angled triangle ANO , we can write

$(R^2) = (AN)^2 + (ON)^2$

$\Rightarrow R^2 = (3)^2 + (R - 0.3)^2$

$\Rightarrow R^2 = 9 + R^2 + 0.09 - 0.6R$

$R = \frac{9.09}{0.6} = 15.15cm \approx 15cm$



From the Lens Maker's formula,

$\frac{1}{f} = (\mu g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

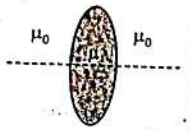
$= \left(\frac{1}{15} - \frac{1}{\infty}\right) = \frac{1}{30} \Rightarrow f_1 = 30cm$

128. (a) A person with defect of myopia can not see distant objects clearly, while that of astigmatism sees objects non-uniform and distorted.

@FAKE_CBSE_X_GRAJ_FB_NET

129. (c) Focal length can be calculated Using lens makers formula,

$$\frac{1}{f}=\left(\frac{\mu}{\mu_0}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$



As $\mu=\mu_0=1.4$

$$\Rightarrow \frac{1}{f}=0 \Rightarrow f \Rightarrow \text{Infinite}$$

130. (d) $\frac{1}{f_1}=\frac{\mu_1-1}{R}, \frac{1}{f_2}=-\left(\frac{\mu_2-1}{R}\right)$

$$\frac{1}{f_{eq}}=\frac{1}{f_1}+\frac{1}{f_2}=\frac{\mu_1-\mu_2}{R}\Rightarrow\frac{R}{f_{eq}}=\mu_1-\mu_2$$

131. (c) Magnification,

$$m=\frac{f}{f+u}=\frac{-f}{-f-f}=+\frac{1}{2}$$

Images distance,

$$v=\frac{uf}{u+f}\Rightarrow v=\frac{-f\times-f}{-f-f}=\frac{f^2}{-2f}=\frac{-f}{2}$$

∴ Distance of image from optical centre $=\frac{f}{2}$

132. (a) $\frac{1}{v_1}+\frac{1}{30}=\frac{1}{10}\Rightarrow v_1=15\text{cm}$

$$\Rightarrow\frac{1}{v_2}-\frac{1}{10}=-\frac{1}{10}$$

$$\Rightarrow v_2=\infty\Rightarrow v_3=30\text{cm}\Rightarrow OV_3=75\text{cm}$$

133. [15]

Magnification, $m=\frac{f}{f+u}$

Thus, $m_1=-m_2\Rightarrow\frac{f}{f-10}=\frac{-f}{f-20}$

$\Rightarrow f=15$ cm

134. [50]

As image coincides with the object, image formed by convex lens should be at the centre of curvature of the convex mirror. If the convex mirror is removed, then, also, image formed the convex lens is at the same location.

Distance of image from object = 12 + 8 + 2 × 15 = 50 cm

135. (c) Given: $\mu_g=1.5, \mu_\lambda=1.42$

$$\frac{1}{f}=(\mu_g-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(i)$$

$$\frac{1}{f_t}=\left(\frac{\mu_g}{\mu_t}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(ii)$$

Now, dividing eq (i) by eq (ii)

$$\frac{f_t}{f}=\frac{\mu_g-1}{\frac{\mu_g}{\mu_t}-1}=\frac{1.5-1}{\frac{1.5}{1.42}-1}=8.875\approx 9.$$

136. (d) Fact based

137. (d) Power of the double convex lens,

$$P=(\mu-1)\left(\frac{1}{R}-\frac{1}{-R}\right)$$

$$P=\frac{(2\mu-1)}{R} \quad ...(1)$$

$$1.5P=\frac{(\mu-1)}{R'}, \frac{1}{1.5}=\frac{2R'}{R}$$

$$R'=\frac{R}{3}$$

Hence, option (d) is correct answer.

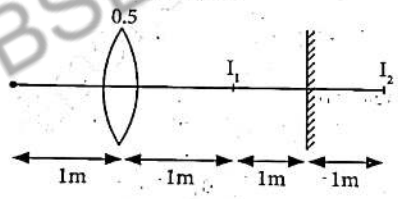
138. (a) Image formed by one will be object for other.

$$\frac{1}{v_1}+\frac{1}{1}=\frac{1}{0.5}\Rightarrow v_1=1\text{m}$$

I_2 will be formed in behind the mirror.

$$\frac{1}{v_3}+\frac{1}{3}=\frac{1}{0.5}\Rightarrow v_3=0.6\text{m}$$

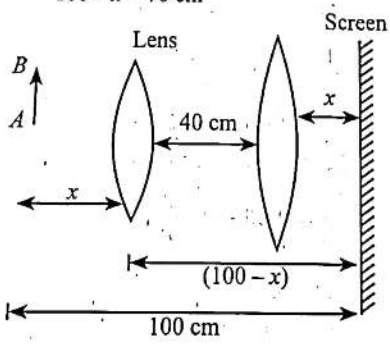
So, final image will be formed at 2.6 m from the mirror, real.



139. [476] Power of the lens, $P=\frac{1}{f}=\left(\frac{N}{100}\right)D$

$2x+40=100\Rightarrow x=30$ cm

$100-x=70$ cm



Using this formula $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$$\frac{1}{70}-\frac{1}{-30}=\frac{1}{f}$$

Power of the lens

$$=\frac{1}{f}=\frac{1}{0.21}\Rightarrow P=\left(\frac{100}{21}\right)D$$

Now, $\frac{N}{100}D=\frac{100}{21}D$

$$N=\frac{10000}{21}=476.19$$

N = 476

140. [60] $\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

$R_1=30$ cm

$R_2=\infty$

$$\frac{1}{f}=(1.5-1)\left(\frac{1}{30}-\frac{1}{\infty}\right), \frac{1}{f}=\frac{0.5}{30}$$

$f=60$ cm

141. (c) Here, $u=-10$cm, $v=+10$ cm, Using, lens formula we have $f=5$ cm

Due to introduction of slab, shift in the source is,

$$t\left(1-\frac{1}{\mu}\right)=1.5\left(1-\frac{1}{\mu}\right)=0.5\text{cm}$$

So, new $u=10-0.5=9.5$ cm

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{v}-\frac{1}{-9.5}=\frac{1}{5}\Rightarrow v=\frac{47.5}{4.5}$$

Hence, shift in the position of image is

$$\frac{47.5}{4.5}-10=\left(\frac{2.5}{4.5}\right)=0.55\text{ cm}$$

142. (*)

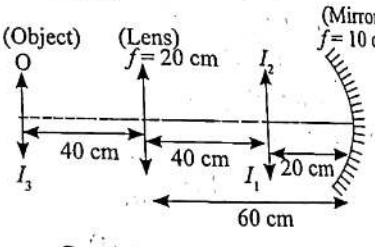
There will be 3 phenomenon

(i) Refraction from lens

(ii) Reflection from mirror

(iii) Refraction from lens

After these phenomena. Image will be on object and will have same size. None of the option depicts so this question is Bonus.



Case 1: Refraction $u=-40$ cm, $f=+20$ cm

∴ $v=+40$ cm (Image I_1) and $m_1=-1$

Case 2: Reflection

$u=-20$ cm, $f=-10$ cm

@FAKE_CBSE_X @RAJ_EDUNET

er of the lens

$= \frac{1}{0.21} \Rightarrow P = \left(\frac{100}{21}\right)D$

$\frac{N}{100}D = \frac{100}{21}D$

$\frac{0000}{21} = 476.19$

6

$= (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

cm

$-1)\left(\frac{1}{30} - \frac{1}{\infty}\right), \frac{1}{f} = \frac{0.5}{30}$

$t = -10\text{cm}, v = +10$ cm. Using

la we have $f = 5$ cm

roduction of slab, shift in the

$1.5\left(1 - \frac{1}{\mu}\right) = 0.5\text{cm}$

$10 - 0.5 = 9.5$ cm

$\Rightarrow v = \frac{47.5}{4.5}$

a the position of image is

$\left(\frac{2.5}{1.5}\right) = 0.55$ cm

phenomenon

from lens

i from mirror

n from lens

nomena. Image will be

ill have same size. None

picts so this question is

(Mirror)

$f = 10$ cm

I_2

I_1

20 cm

60 cm

$= -40$ cm, $f = +20$ cm

ge I_1) and $m_1 = -1$

cm

$\therefore v = -20$ cm (image I_2) and $m_2 = -1$

Case 3: Refraction

$u = -40$ cm; $f = +20$ cm

$\therefore v = +40$ cm (image I_3) and $m_3 = -1$

Total magnification $= m_1 \times m_2 = -1$

$\therefore$ size of final image = size of object

Final image formed at 40 cm from convergent lens and 100 cm from convergent mirror.

No option is matching (Bonus).

143. (*b*) For convex lens $\frac{1}{f_1} = (\mu - 1)\left(\frac{2}{R}\right)$

$\frac{1}{18} = (1.5 - 1)\frac{2}{R} \Rightarrow R = 18$ cm

For plano convex liquid lens

$\frac{1}{f_2} = (\mu_l - 1)\left(\frac{-1}{R}\right), \frac{1}{f_2} = \frac{\mu_l - 1}{-18}$

When liquid is filled between lens and mirror

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \Rightarrow \frac{1}{27} = \frac{1}{18} - \left(\frac{\mu_l - 1}{18}\right)$

$\frac{1}{27} = \frac{2 - \mu_l}{18}, 2 - \mu_l = \frac{18}{27} = \frac{2}{3}$

$\mu_l = 2 - \frac{2}{3} = \frac{4}{3}$

144. (*d*) Image by convex lens:

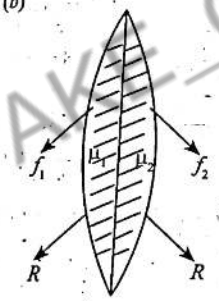
$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}; \frac{1}{v} + \frac{1}{20} = \frac{1}{5}$

$v = \frac{20}{3}$ cm

Image by concave lens : $u = \left[\frac{20}{3} - 2\right] = \frac{14}{3}$ cm

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}; \frac{1}{v} - \frac{3}{14} = -\frac{1}{5}$ $v = 70$ cm

145. (*b*)



$\frac{1}{f} = \frac{(1 - \mu_1)}{R} + \frac{(\mu_2 - 1)}{R}$

$\frac{1}{f} = \frac{(\mu_2 - \mu_1)}{R} = f = \frac{R}{\mu_2 - \mu_1}$

146. (*d*) Magnification is 2

$m = \frac{v}{u} = \pm 2$ ...(i)

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ ...(ii)

from equation (i) and (ii)

If image is real, $x_1 = \frac{3f}{2}$

If image is virtual, $x_2 = \frac{f}{2}$; $\frac{x_1}{x_2} = 3:1$

147. (*d*) $1 - m = \frac{v}{f} \Rightarrow m = 1 - \frac{v}{f}$

At $v = a$, $m_1 = 1 - \frac{a}{f}$

At $v = a + b$, $m_2 = 1 - \frac{a+b}{f}$

$m_2 - m_1 = c = \left[1 - \frac{a+b}{f}\right] - \left[1 - \frac{a}{f}\right]$

$c = \frac{-b}{f} \Rightarrow f = \frac{-b}{c}$

148. (*d*) Using lens formula:

$\frac{1}{v} - \frac{1}{-20} = \frac{1}{0.30}$

$\Rightarrow \frac{1}{v} = \frac{1}{0.30} - \frac{1}{20} \Rightarrow \frac{1}{v} = \frac{197}{60}$

$\therefore \frac{1}{v} - \frac{1}{u} = \frac{1}{f}, \therefore \frac{dv}{dtv^2} + \frac{du}{dtu^2} = 0$

$\frac{dv}{dt} = \left(\frac{60}{197 \times 20}\right)^2 \times (-5)$

$\frac{dv}{dt} = 1.16 \times 10^{-3}$ m/s

149. (*b*) $\frac{1}{f_1} = (\mu_1 - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right); \frac{1}{f_2}$

$= (\mu_2 - 1)\left(\frac{1}{\infty} - \frac{1}{R}\right)$

$\frac{1}{f_1} = \frac{(\mu - 1)}{R}; \frac{1}{f_2} = \frac{-(\mu_2 - 1)}{R}$

Given, $f_2 = 2f_1 \Rightarrow \frac{1}{f_1} = \frac{2}{f_2}$

$\Rightarrow \frac{\mu_1 - 1}{R} = \frac{2(\mu_2 - 1)}{R}$

150. (*a*) If the setup is immersed in water without disturbing the object the focal length will decrease and image will disappear.

151. (*a,c,d*) When $n_1 = n_2 = n$

$\frac{1}{f} = (n - 1) \times \frac{2}{R}$

So $f = \frac{R}{2(n-1)}$ ...(i)

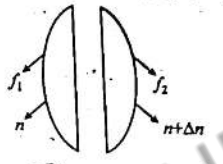
2nd case: $\frac{1}{f_1} = \frac{n-1}{R}$

$\frac{1}{f_2} = \frac{(n + \Delta n) - 1}{R}$

$\frac{1}{f_m} = \frac{1}{f + \Delta f} = \left(\frac{n-1}{R}\right) + \frac{(n + \Delta n) - 1}{R}$

$= \frac{2(n-1) + \Delta n}{R}$

$\Delta f = \left(\frac{R}{2(n-1) + \Delta n}\right) - \left(\frac{R}{2(n-1)}\right)$



$= \frac{R}{2}\left[\frac{(n-1) - (n-1+\Delta n)}{(n-1+\Delta n)(n-1)}\right] = \frac{-\Delta n}{(n-1)} \times \frac{R}{2}$

$\frac{\Delta f}{f} = -\frac{\Delta n}{2(n-1)}$ ...(ii)

(*a*) Relation beteeen $\frac{\Delta f}{f}$ and $\frac{\Delta n}{n}$ is independent of R so (*a*) is correct.

(*b*) $2n - 2 < n$ because $n < 2$

$\Rightarrow \frac{\Delta f}{f} = \frac{1}{2}\left|\frac{\Delta n}{n-1}\right| > \frac{\Delta n}{n}$

So $\frac{\Delta f}{f} > \left|\frac{\Delta n}{n}\right|$

So (*b*) is wrong

(*c*) $|\Delta f| = \frac{f \Delta n}{2(n-1)} = \frac{(20 \times 10^{-3})}{2(1.5-1)}$

$= 20 \times 10^{-3} = 0.02$ cm

So (*c*) is correct

(*d*) If $\frac{\Delta n}{n} < 0$ then $\frac{\Delta f}{f} >$ 0 from equation (ii)

So (*d*) is correct

152. [1.39]

For the given lens

$u = -30$ cm, $v = 60$ cm

& $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ on solving : $f = 20$ cm

also $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

on differentiation

$-\frac{df}{f^2} = -\frac{dv}{v^2} + \frac{du}{u^2}$

$\Rightarrow \left(\frac{df}{f^2}\right)_{max} = \frac{dv}{v^2} + \frac{du}{u^2}$

@FAKE_CBSE_X_@RAJ_EDUNET

$$\frac{df}{f}=f\left[\frac{dv}{v^2}+\frac{du}{u^2}\right]$$

and $\frac{df}{f}\times 100=f\left[\frac{dv}{v^2}+\frac{du}{u^2}\right]\times 100\%$

$f=20$ cm, $|u|=x_2-x_1=30$ cm

Since there are 4 divisions in 1 cm on scale

$du=0.25+0.25=0.50$

$|v|=x_3-x_2=60$ cm

$dv=0.25+0.25=0.50$ cm

$\therefore \frac{df}{f}\times 100=20$

$$\left[\frac{0.50}{(60)^2}+\frac{0.50}{(30)^2}\right]\times 100\%$$

$$=10\left[\frac{1}{3600}+\frac{1}{900}\right]\times 100\%$$

$$=10\left[\frac{5}{36}\right]\%=\frac{50}{36}\%\approx 1.39\%$$

153. (*a*) Using formula, $d=h\left(1-\frac{1}{\mu}\right)$

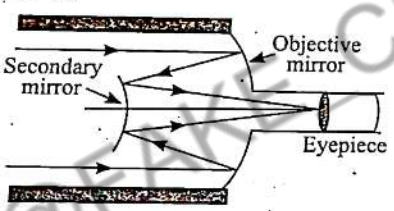
$\Rightarrow 30=h\left(1-\frac{3}{5}\right)$

$\left[\because \text{Given, } d=30\text{cm}, \mu=\frac{5}{3}\right]$

$\Rightarrow 30=h\times\frac{2}{5}$

$\therefore h=75$ cm

154. (*d*)



It has advantage of a large focal length in a short telescope which is used to move the eyepiece outside the telescopic tube.

155. [41]

$u=\frac{h}{h'}=\frac{5.25}{5.00}$

Least count $=\left(1-\frac{49}{50}\right)\frac{1}{20}$cm

$=\frac{1}{50}\times\frac{1}{20}$ cm

$=0.01$ mm

$\because u=\frac{h}{h'}\Rightarrow \ln u=\ln h-\ln h'$

$\Rightarrow \frac{du}{u}=\frac{dh}{h}-\frac{dh'}{h'}$

$\Rightarrow du=\left(\frac{dh}{h}-\frac{dh'}{h'}\right)u$

$\Rightarrow du=\left[\frac{0.01}{5.25}+\frac{0.01}{5.00}\right]\frac{5.25}{5.00}$

$\therefore u=\frac{41}{10}\times 10^{-3}$

156. (*a*) $|f_0|+|f_e|=30$ cm (Given)

As, $\left|\frac{f_0}{f_e}\right|=2$ (given)

$\Rightarrow |f_0|=2|f_e|$

$\therefore |f_0|+\frac{|f_0|}{2}=30\Rightarrow |f_0|=\frac{2}{3}\times 30=20\,cm$

157. [5] Given, (50 *VSD* = 49 *MSD*)

$\therefore 1\,VSD=\frac{49}{50}MSD$

$L.C=1\,MSD-1\,VSD$

$=1-\frac{49}{50}MSD$

$=\frac{1}{50}MSD$ ... (i)

Since, 40 division are in 1 cm on main scale

$\therefore 1MSD=\frac{1}{40}cm$

$L.C=\frac{1}{50}\times\frac{1}{40}cm=\frac{1}{2000}cm$

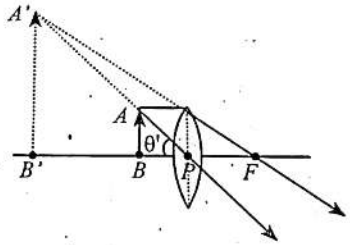
$=6.5\times 10^{-3}$ cm $=5\times 10^{-6}$ m

158. (*a*) Microscope has a convex lens to magnify the object image.

It is clear that angle for image and object is same. Hence the angular size of image and object is same.

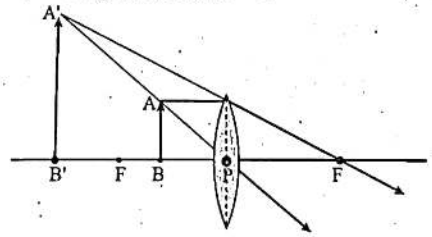
As object is so close to lens.

Hence, magnification is achieved.



159. [25] Given, distance of object, $D=25$cm

Magnification, $m=6$.



$m=1+\frac{D}{f}\Rightarrow 6=1+\frac{25}{f}\Rightarrow f=5$cm

For compound microscope,

$m=m_o\times m_e=\frac{LD}{f_o f_e}\Rightarrow f_e$

$=\frac{LD}{mf_o}=\frac{60\times 25}{12\times 5}=25$cm

160. (*a*) For least distance of distinct vision

$MP.=\frac{L}{f_0}\left(1+\frac{D}{f_e}\right)$

$\Rightarrow 375=\frac{150\times 10^{-3}}{5\times 10^{-3}}\left(1+\frac{25\times 10^{-2}}{f_e}\right)$

$\therefore f_e\approx 21.7\times 10^{-3}m$

$f_e\approx 22$mm

161. (*b*) $m=\frac{f_0}{f_e}$

$5=\frac{f_0}{f_e}$

$\Rightarrow f_0=5f_e\Rightarrow f_0+f_e=60\Rightarrow 6f_e=60$

$\therefore f_e=10$

162. [6.25]

For compound microscope the magnification when final image by eye-piece is formed at $D=25$ cm (least distance for clear vision)

$m=\frac{L}{f_0}\left(1+\frac{D}{f_e}\right)=100$

$\Rightarrow \frac{20}{1}\left(1+\frac{25}{f_e}\right)=100$

$\Rightarrow 1+\frac{25}{f_e}=5\Rightarrow \frac{25}{f_e}=4$

$\Rightarrow f_e=\frac{25}{4}=6.25$ cm

163. [50.00]

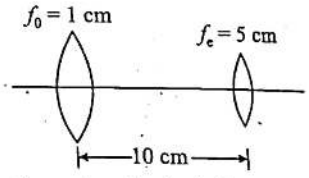


Image by objective is formed at the focus of eye-piece

$\therefore$ For objective, $v=5, f=1$ cm

$\frac{1}{5}-\frac{1}{u}=\frac{1}{1}\Rightarrow \frac{1}{5}-1=\frac{1}{u}$

$\therefore |u|=\frac{5}{4}$cm

$\Rightarrow |u|=\frac{50}{40}\text{cm}=\frac{n}{40}\text{cm}\quad \therefore n=50$

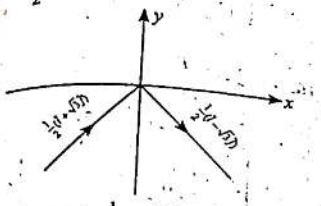
164. (*a*)

165. (*d*) To minimise attenuation, wavelength of carrier waves is close to 1500 nm

@TAKE_CBSE_X_@RAJ_EDUNET

JEE-Advanced

1. (a) After reflection, the only component of incident light's propagation direction perpendicular to the flat mirror changes sign. We can assume that the plane mirror's normal is parallel to it because the y component changes after reflection $\hat{j}$. As a result, the angle of incidence is the angle formed by the unit vectors $\frac{1}{2}(\hat{i}+\sqrt{3}\hat{j})$ and $\hat{j}$.

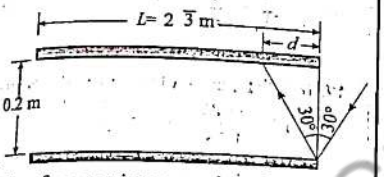


$$\Rightarrow \cos(i) = \frac{1}{2}(i+\sqrt{3}j)\cdot j$$

$$\Rightarrow i = \cos^{-1} = \frac{\sqrt{3}}{2} = 30^\circ$$

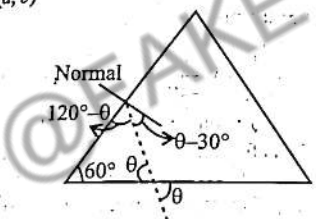
2. (b) $d = 0.2 \tan 30^\circ = \frac{0.2}{\sqrt{3}}$

$$\frac{L}{d} = \frac{2\sqrt{3}}{0.2/\sqrt{3}} = 30$$



Therefore, maximum number of reflections are 30.

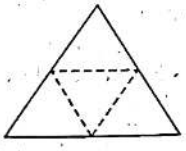
3. (a, b)



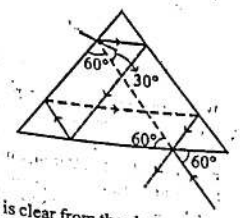
As we can see, for $\theta = 30^\circ$, the ray will incident normally and hence will retrace its path.

$\Rightarrow$ (a) is correct

Considering the symmetry of the situation, we can have :



$\Rightarrow$ (b) is correct



As is clear from the above diagram, ray comes out.

$\Rightarrow$ (c) is not correct

Also, as is clear from the above diagram, total number of reflections = 5.

(d) is not correct.

4. [13.97] Resultant intensity at

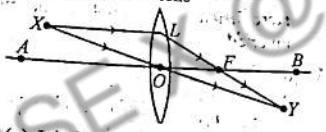
$$I_P = I_A + I_B + I_C$$

$$= \frac{P_A}{4\pi(PA)^2} + \frac{P_B}{4\pi(PB)^2}\cos 60^\circ + I_C\cos 60^\circ$$

$$= \frac{90}{4\pi(3)^2} + \frac{180}{4\pi(1.5)^2}\cos 60^\circ + 20\cos 60^\circ$$

$$= 0.79 + 3.18 + 10 = 13.97 \text{ W/m}^2$$

5. Steps I In case of a lens



(a) Join X and Y. The point O, where the line XY cuts the optic axis AB, is the optical centre of the lens.

(b) Draw a line parallel to AB from point X. Let it cuts the lens at L. Join L and Y. The point F where the line LY cuts the optic axis AB is the focus (second focus) of the lens F.

6. (d) Distance of point A is $f/2$

Ref image. 1

Let A' is the image of A from mirror, for this image

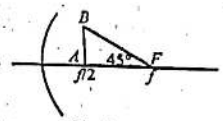
$$\frac{1}{v} + \frac{1}{-f/2} = \frac{1}{-f}\quad \frac{1}{v} = \frac{2}{f} - \frac{1}{f} = \frac{1}{f}$$

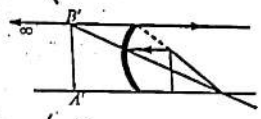
Ref image. 2

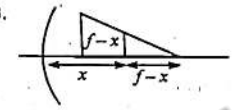
Image of line AB should be perpendicular to the principle axis & image of F will form at infinity, therefore correct image diagram is Ref image. 3

$$\frac{f}{f-u} = \frac{h_2}{h_1}$$

$$\Rightarrow h_2 = \frac{-f(f-x)}{-f+x}\quad h_2 = f.$$

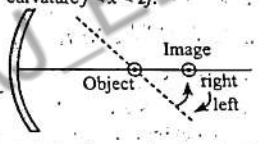
1.


2.


3.


7. (b) The location should be as shown in the figure since the object and image move in opposite directions.

Object lies between focus and centre of curvature $f < x < 2f$.

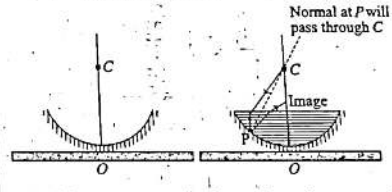


8. (a) The formula $\frac{1}{V} + \frac{1}{u} = \frac{1}{f}$ is valid only for small size Without this approximation, the relation would become very complicated.

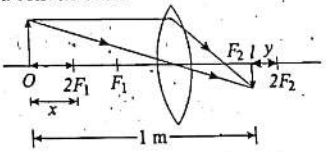
Laws of reflection are valid for all surfaces. In fact every curved surface can be considered to be an infinitesimally small plane surface at the point of reflection.

Angle of incidence = Angle of reflection

9. (d) The ray diagram is shown in figure. Therefore, the image will be real and between C and O.



10. (c) Image can be formed on the screen if it is real. Real image of reduced size can be formed by a concave mirror or a convex lens.



@FAKE_OBSEY @RAJ_BOUNCER

A diminished real image is formed by a convex lens when the object is placed beyond $2f$ and the image of such object is formed between f and $2f$ on other side.

Thus, $d > (2f + 2f)$

$4f < 0.1\text{m}$ or $f < 0.25$ m

11. (c, d) For the given concave mirror: $f = -24$ cm

Mirror formula is $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

so, $v=\frac{uf}{u-f}$

Case 1: $u = -42$ cm,

$v=\frac{-24\times(-42)}{-42+24}=-56$ cm

Satisfies

Case 2: $u = -48$ cm

$v=\frac{-24\times(-48)}{-48+24}=-48$ cm

Satisfies

Case 3: $u = -66$ cm

$v=\frac{-24\times(-66)}{-66+24}=-37.71$ cm

Does not satisfy .

Case 4: $u = -78$ cm

$v=\frac{-24\times(-78)}{-78+24}=-34.66$ cm

Does not satisfy

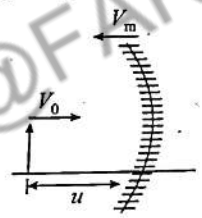
Therefore incorrectly recorded data set are (66,33) and (78,39)

12. [3] We have, $u = -30$ cm, $f = -10$ cm

$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-10}-\frac{1}{-30}=\frac{1}{30}-\frac{1}{10}$$

$$=\frac{1-3}{30}=\frac{-1}{15}$$

So, $v = -15$



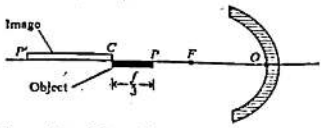
As, $\vec{V}_{I,M}=-\left(\frac{v}{u}\right)^2\vec{V}_{O,M}$

$\Rightarrow \vec{V}_I-\vec{V}_M=-\left(\frac{v}{u}\right)^2(\vec{V}_o-\vec{V}_m)$

$\Rightarrow 0-\vec{V}_M=-\frac{1}{4}(15\hat{i}-\vec{V}_m)$

$\Rightarrow -\vec{V}_M=-\frac{15}{4}\hat{i}+\frac{1}{4}\vec{V}_M \Rightarrow -\vec{V}_M=3\hat{i}$

13. F = focus, C = centre of curvature



When the object lies between F and C, image is real, elongated and inverted. As one end of rod just touches its image, this end should lie at C. Because image of object at C is at C itself.

Let P' be the image of other end of rod P.

For P

$u=-(2f-f/3)=-\frac{5f}{3}$

Applying the mirror formula : $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

or $\frac{1}{v}-\frac{3}{5f}=\frac{1}{-f}\Rightarrow\frac{1}{v}=\frac{3}{5f}-\frac{1}{f}$

or $v=-\frac{5f}{2}$ or $OP'=\frac{5f}{2}$

$\therefore$ Length of image of rod

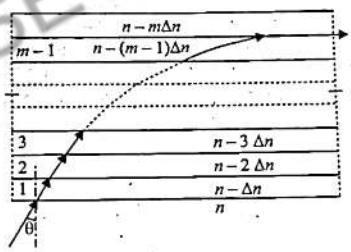
$CP' = OP' - OC = \frac{5f}{2}-2f=\frac{f}{2}$

$\therefore$ Magnification $=-\frac{f/2}{f/3}=-1.5$

Here, negative sign implies that image is inverted.

14. (a) But this value of refractive index is not possible.

$\Delta n = 0.1$



$n\sin\theta = (n - m\Delta n)\sin 90°$

$1.6\sin\theta = n - m\Delta n$

$1.6\sin 30° = [1.6 - m(0.1)]\sin 90°$

$1.6\times\frac{1}{2} = 1.6 - m(0.1)$

$1.6 - 0.1m = 0.8$

$0.1m = 0.8$

$m = 8$

15. (c) On point Q angle of incidence is equal to critical angle θ_c, where

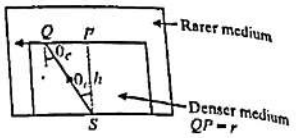
$\sin\theta_c=\frac{\mu_l}{\mu_{block}}=\frac{r}{\sqrt{r^2+h^2}}\times 2.72$

In ΔPQS, $\sin\theta_c=\frac{r}{\sqrt{r^2+h^2}}$

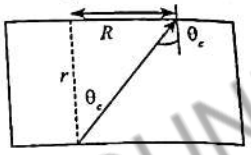
$\therefore \frac{\mu_l}{\mu_{block}}=\frac{r}{\sqrt{r^2+h^2}}$

$\mu_l=\frac{r}{\sqrt{r^2+h^2}}\times 2.72$

$=\frac{5.77}{11.54}\times 2.72 = 1.36$



16. (a) $\tan c=\frac{R}{8}$



Using Snell's law,

$\frac{4}{3}\sin c = 1\times\sin 90°$

$\sin c=\frac{3}{5}$

$C = 37°$

$\frac{3}{4}=\frac{R}{8}$

$R = 6$ cm

17. (c) Distance of object from the mirror

$=15+\frac{33.25}{1.33}=40$ cm

Distance of image from the mirror

$=15+\frac{25}{1.33}=33.8$ cm

For the mirror, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

$\therefore \frac{1}{-33.8}+\frac{1}{-40}=\frac{1}{f}\Rightarrow f=-18.3$ cm

$\therefore$ Most suitable answer is (c).

NOTE After reflection from the mirror, ray of light is passing from rarer to denser. So after refraction from plane surface of water image distance will increase μ-times. Therefore, after the mirror this distance is μ-times smaller.

18. (a) Critical angle $\theta_C=\sin^{-1}\frac{1}{\mu}$

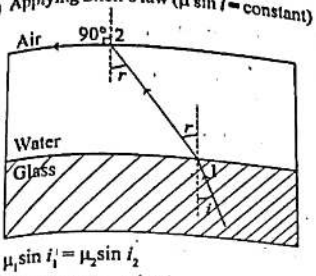
Wavelength increases in the sequence of VIBGYOR. According to Cauchy's formula refractive index (μ) decreases as the wavelength increases. Hence the refractive index will increase in the sequence of ROYGBIV. The critical angle θ_C will thus increase in the same order VIBGYOR.

@FAKE_CBSE_X @RAJ_EDUNET

For green light the incidence angle is just equal to the critical angle. For yellow, orange and red the critical angle will be greater than the incidence angle. So, these colours will emerge from the glass air interface.

19. (c) When the object is placed at the centre of the glass sphere, the rays from the object fall normally on the surface of the sphere and emerge undeviated.

20. (b) Applying Snell's law ($\mu \sin i$ = constant)



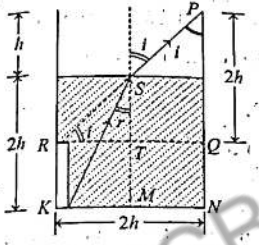
$\mu_1 \sin i_1 = \mu_2 \sin i_2$

Here, $\mu_1 = \mu_{glass}$, $i_1 = i$

$\mu_2 = \mu_{air} = 1$ and $i_2 = 90°$

$\therefore \mu_g \sin i = (1)(\sin 90°)$ or $\mu_g = \dfrac{1}{\sin i}$

21. (b) $PQ = QR = 2h \Rightarrow \angle i = 45°$



$ST = RT = h = KM = MN$

$\therefore$ So, $KS = \sqrt{h^2 + (2h)^2} = h\sqrt{5}$

$\therefore \sin r = \dfrac{h}{h\sqrt{5}} = \dfrac{1}{\sqrt{5}}$

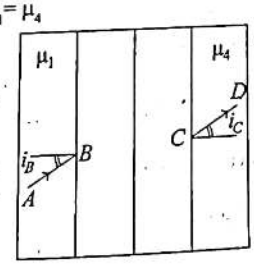
$\therefore \mu = \dfrac{\sin i}{\sin r} = \dfrac{\sin 45°}{1/\sqrt{5}} = \sqrt{\dfrac{5}{2}}$

22. (d) Applying Snell's law at B and C, $\mu \sin i$ = Constant or $\mu_1 \sin i_B = \mu_4 \sin i_C$

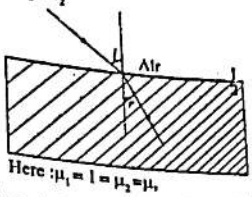
But $AB \| CD$

$\therefore i_B = i_C$

or $\mu_1 = \mu_4$



NOTE The Snell's law, $\mu = \dfrac{\sin i}{\sin r}$ is derived from $\mu \sin i$ = constant or $\mu_1 \sin i_1 = \mu_2 \sin i_2$

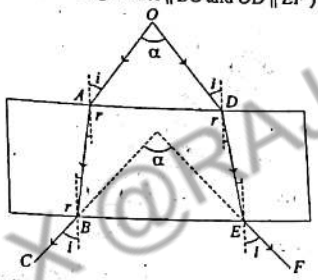


Here : $\mu_1 = 1 = \mu_2 = \mu$,

$\therefore \sin i = \mu \sin r$ or $\mu = \dfrac{\sin i}{\sin r}$

23. (b) Divergence angle will remain unchanged because in case of a glass slab every emergent ray is parallel to the incident ray. However, the rays are displaced slightly towards outer side.

(In the figure $OA \| BC$ and $OD \| EF$)



24. (a) $r + r' + 90° = 180°$

$\therefore r' = 90° - r$

Further, $i = r$

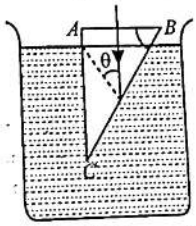
Applying Snell's law, $\mu_D \sin i = \mu_R \sin r'$

or $\mu_D \sin r = \mu_R \sin(90° - r)$ $\mu_R \cos r$

$\therefore \dfrac{\mu_R}{\mu_D} = \tan r, \theta_C = \sin^{-1}\dfrac{\mu_R}{\mu_D} = \sin^{-1}(\tan r)$

25. (a) Let θ_c be the critical angle on face BC, then

$\sin\theta_c = \dfrac{\mu_w}{\mu_g} = \dfrac{4/3}{3/2} = \dfrac{8}{9}$



Angle of incidence on face BC is $= \theta$

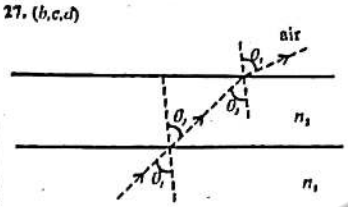
Total internal reflection (TIR) will take place on this surface if,

$i > \theta_c$ or $\theta > \theta_c$ or $\sin\theta > \sin\theta_c$ or $\sin\theta > \dfrac{8}{9}$

26. (a) $\lambda = \dfrac{v}{f}$

In moving from air to glass, f remains unchanged while v decreases. Hence, λ should decrease.

27. (b,c,d)



$\sin\theta > \dfrac{1}{n_1}$ (Given)

i.e., $\sin\theta_1 > \dfrac{1}{n_1}$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\sin\theta_2 = \dfrac{n_1 \sin\theta_1}{n_2}$

if $n_1 = n_2$ then $\theta_2 = \theta_1$

$n_2 \sin\theta_2 = (1) \sin\theta_3$

$\sin\theta_3 = n_2 \sin\theta_2$

$\sin\theta_3 = n_1 \sin\theta_1$

$\sin\theta_1 = \dfrac{\sin\theta_3}{n_1} > \dfrac{1}{n_1}$

$\sin\theta_3 > 1$

$\theta_3 > 90°$

This means ray cannot enter air.

For $n_1 > n_2$; $\sin\theta_1 = \dfrac{n_2}{n_1}\sin\theta_2 > \dfrac{1}{n_1}$

$\sin\theta_2 < \dfrac{1}{n_2}$

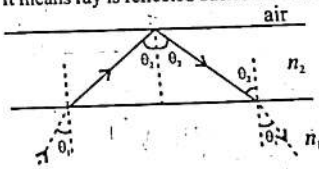
For surface 2 - air interface

$n_2 \sin\theta_2 = \sin\theta_3$

$\sin\theta_2 = \dfrac{\sin\theta_3}{n_2} > \dfrac{1}{n_2}$

$\theta_2 > 90°$

It means ray is reflected back in medium-2



For surface 1 and surface 2 interface

$n_2 \sin\theta_2 = n_1 \sin\theta_1$

$\sin\theta_{2C} = \dfrac{n_1}{n_2}$

@FAKE_CBSE_X@RAJ_EDUNET

θ_{2C}: critical angle

For ray to enter medium –1

$\theta_2 < \theta_{2C}$

$\sin\theta_2 < \sin 2\theta_c$

$\frac{n_1}{n_2}\sin\theta_1 < \frac{n_1}{n_2}$

$\sin\theta_1 < 1$

$\theta_1 < 90°$, which is true.

Hence, ray enters medium - 1

For $n_2 > n_1$

$\frac{n_2}{n_1}\sin\theta_2 > \frac{n_2}{n_1}$

$\sin\theta_2 > \frac{1}{n_2}$

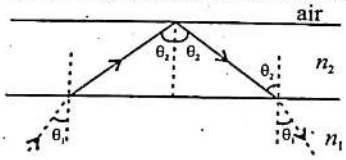
For surface 2 - air interface

$n_2 \sin\theta_2 = \sin\theta_3$

$\sin\theta_2 = \frac{\sin\theta_3}{n_2} > \frac{1}{n_2}$

$\theta_2 > 90$

It means ray reflected back in medium - 2



$n_2 \sin\theta_2 = n_1 \sin\theta_1$

$\sin\theta_1 = \frac{n_2}{n_1}\sin\theta_2$

$\sin\theta_{2C} = \frac{n_1}{n_2}$; $\theta_{2C} \rightarrow$ critical angle

For ray to enter medium - 1

$\theta_2 < \theta_{2C}$

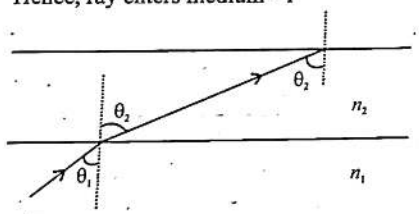
$\sin\theta_2 < \sin\theta_{2C}$

$\frac{n_1}{n_2}\sin\theta_1 < \frac{n_1}{n_2}$

$\sin\theta_1 > 1$

$\theta_1 = 90°$, which is true.

Hence, ray enters medium - 1



$n_1 \sin\theta_1 = n_1 \sin\theta_2 \Rightarrow n_2 = 1$

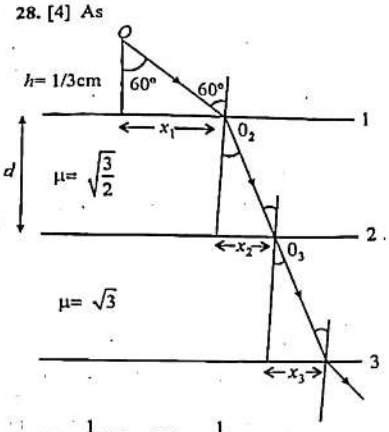
$n_1 \sin\theta_1 = \sin\theta_2$

$\sin\theta_1 = \frac{\sin\theta_2}{n_1} > \frac{1}{n_1}$

$\sin\theta_2 > 1 \Rightarrow \theta_2 = 90°$

$\therefore$ Ray is reflected back in medium.

28. [4] As



$x_1 = \frac{1}{3} \times \tan 60° = \frac{1}{\sqrt{3}}$ cm

At interface - 1

$1 \sin 60° = \sqrt{\frac{3}{2}} \sin\theta_2$

$\Rightarrow \theta_2 = 45°$

So, $x_2 = d \tan 45° = \frac{\sqrt{3}-1}{2}$

At interface - 2

Again $\sqrt{\frac{3}{2}} \sin 45° = \sqrt{3} \sin\theta_3$

$\Rightarrow \theta x_3 = 30°$

So, $x_3 = d \tan 30° = \frac{\sqrt{3}-1}{2\sqrt{3}}$

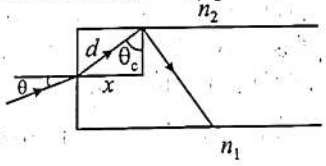
So, $x_1 + x_2 + x_3 = \frac{1}{\sqrt{3}} + \frac{\sqrt{3}-1}{2}\left(1+\frac{1}{\sqrt{3}}\right)$

$= \frac{1}{\sqrt{3}} + \frac{(\sqrt{3}-1)(\sqrt{3}+1)}{2\sqrt{3}} = \frac{1}{\sqrt{3}} + \frac{1}{\sqrt{3}} = \frac{2}{\sqrt{3}}$

So 1 unit shift light ray by $\frac{2}{\sqrt{3}}$, therefore to shift light ray by $l = \frac{8}{\sqrt{3}}$, no. of units needed,

$n = \frac{\frac{8}{\sqrt{3}}}{\frac{2}{\sqrt{3}}} = 4$

29. [50.00] For maximum time the ray of light must undergo *TIR* at all surfaces at minimum angle *i.e.*, θ_C



For *TIR* $n_1 \sin\theta_C = n_2$

$\sin\theta_C = \frac{1.44}{1.5}$

In above, $\sin\theta_C = \frac{x}{d}$

$d = \frac{x}{\sin\theta_C}$

Similarly, $D = \frac{L}{\sin\theta_C}$

Where L = length of tube

D = length of path of light

Time taken by light

$t = \frac{D}{c} = \frac{L/\sin\theta_C}{3\times10^8}$

$t = 50 \times 10^{-9}$ s

30. (*b*) The meta-materials' refractive index is found to be negative. The speed of light in a meta material, like that of regular materials, is n^{th} part of the speed of light in vacuum; only the modulus of the negative refractive index is considered.

$V = \frac{C}{|n|}$

31. (*b*) Applying Snell's Law,

$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_1}{n_2}$

Since $\sin\theta_1$ and n_1 are positive but n_2 is negative, the fraction $\frac{n_1}{n_2} \times \sin\theta_1$ (say k) is negative.

$\theta_2 = \sin^{-1}k$ where k is negative.

Therefore $-\frac{\pi}{2} < \theta_2 < 0$.

Note that angles measured in anticlockwise direction is positive and clockwise direction is negative.

32. (*a*) Wavefronts are parallel in both media. Therefore, light which is perpendicular to wavefront travels as a parallel beam in each medium.

33. (*c*) All points on a wavefront are at the same phase.

$\therefore \phi_d = \phi_c$ and $\phi_f = \phi_e$.

$\therefore \phi_d - \phi_f = \phi_c - \phi_e$

34. (*b*) Ray of light which is perpendicular to wavefront bends towards the normal in medium-2 during refraction. So, medium-2 is denser or its speed in medium-1 is more.

35. Speed of light in vacuum, $c = \frac{1}{\sqrt{\varepsilon_0\mu_0}}$

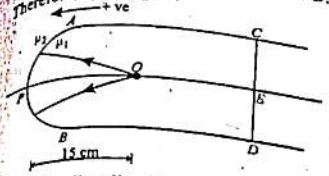
and speed of light in medium, $v = \frac{1}{\sqrt{\varepsilon\mu}}$

Therefore, refractive index of the medium is

$\mu = \frac{c}{v} = \frac{1/\sqrt{\varepsilon_0\mu_0}}{1/\sqrt{\varepsilon\mu}} = \sqrt{\frac{\varepsilon\mu}{\varepsilon_0\mu_0}}$

@FAKE_CBSE_X @RAJ_EDUCENT

36. Rays starting from O will suffer single refraction from spherical surface APB. Therefore, applying



$$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$$

$$\frac{1.0}{v}-\frac{2.0}{-15}=\frac{1.0-2.0}{-10}$$

$$\frac{1}{v}=\frac{1}{10}-\frac{1}{7.5} \text{ or } v=-30 \text{ cm}$$

Therefore, image of O will be formed at 30 cm to the right of P. Note that image will be virtual. There will be no effect of CED.

37. $\lambda_{medium}=\frac{\lambda_{air}}{\mu}=\frac{6000}{1.5}=4000\text{Å}$

$$f=\frac{v_{air}}{\lambda_{air}}=\frac{v_{medium}}{\lambda_{medium}}=\frac{3.0\times10^8}{6.0\times10^{-7}}$$

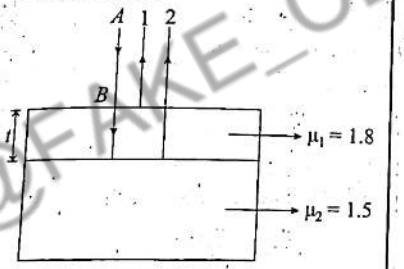
$=5.0\times10^{14}$ Hz

Frequency remains unchanged.

38. $v=\frac{c}{\mu}=\frac{3\times10^8}{1.5}=2.0\times10^8$ m/s

$$\lambda=\frac{v}{f}=\frac{2.0\times10^8}{5.0\times10^{14}}=4.0\times10^{-7}\text{ m}$$

39. Incident ray AB is partly reflected as ray 1 from the upper surface and partly reflected as ray 2 from the lower surface of the layer of thickness t and refractive index μ_1=1.8 as shown in figure. Path difference between the two rays would by



$\Delta x=2\mu_1 t=2(1.8)t=3.6t$

Ray 1 is reflected from a denser medium, therefore, it undergoes a phase change of π, whereas the ray 2 gets reflected from a rarer medium, therefore, there is no change in phase of ray 2.

Hence, phase difference between rays 1 and 2 would be $\Delta\varphi=\pi$. Therefore, condition of constructive interference will be

$$\Delta x=\left(n-\frac{1}{2}\right)\lambda \text{ where } n=1,2,3\ldots \text{ or}$$

$$3.6t=n-\frac{1}{2}\lambda$$

Least value of t is corresponding to $n=1$ or

$$t_{min}=\frac{\lambda}{2\times3.6} \text{ or } t_{min}=\frac{648}{7.2}\text{ nm}$$

or $t_{min}=90$ m

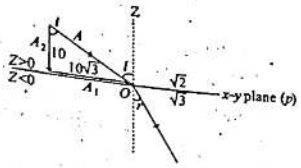
40. Let us take $A=A_1+A_2$.

Here $A_1=(6\sqrt{3}\hat{i}+8\sqrt{3}\hat{j})$, a vector in x-y plane

A_1 or $|A_1|=\sqrt{(6\sqrt{3})^2+(8\sqrt{3})^2}=10\sqrt{3}$ units

$A_2=-10\hat{k}$

A_2 or $|A_2|$ units



$$\sin i=\frac{10\sqrt{3}}{\sqrt{(10)^2+(10\sqrt{3})^2}}=\frac{\sqrt{3}}{2}\Rightarrow i=60^\circ$$

Applying Snell's law at O,

$\sqrt{2}\sin i'=\sqrt{3}\sin r$

Putting the value of sin i, we get $r=45^\circ$

Let $\hat{P}$ is a unit vector in the direction of A_1, then

$$\hat{p}=\frac{A_1}{A_1}=\frac{1}{10\sqrt{3}}\left(6\sqrt{3}\hat{i}+8\sqrt{3}\hat{j}\right)$$

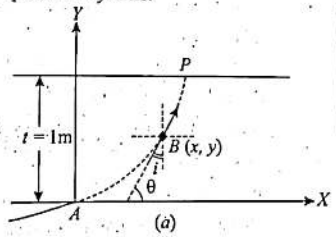
Now, we have to find a unit vector (having magnitude 1) in the direction of OM and let this is $\hat{n}$. Then

$$\hat{n}=(1\sin r)\hat{p}+(1\cos r)(-\hat{k}) \qquad (r=45^\circ)$$

$$=\frac{1}{\sqrt{2}}\frac{1}{10\sqrt{3}}\left(6\sqrt{3}\hat{i}+8\sqrt{3}\hat{j}\right)-\frac{1}{\sqrt{2}}\hat{k}$$

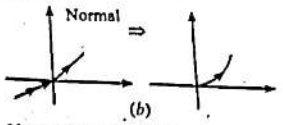
$$=\frac{1}{5\sqrt{3}}\left(3\hat{i}+4\hat{j}-5\hat{k}\right)$$

41. (*a*) Refractive index is a function of y. It varies along y-axis i.e. the boundary separating two media is parallel to x-axis or normal at any point will be parallel to y-axis.



(*a*)

Secondly, refractive index increases as y is increased. Therefore, ray of light is travelling from rarer to denser medium i.e. it will bend towards the normal and shape of its trajectory will be as shown below.



(*b*)

Now, refer to figure (*a*)

Let I be the angle of incidence at any point B on its path

$\theta=90^\circ-I$

or $\tan\theta=(90^\circ-I)=\cot I$

or slope $=\cot I$

(*b*) but $\tan\theta=\frac{dy}{dx}$

$$\therefore \frac{dy}{dx}=\cot I \qquad \ldots(i)$$

Applying Snell's law at A and B

$n_A\sin i_A=n_B\sin i_B\Rightarrow n_A=1$ because $y=0$

$\sin i_A=1$ because $i_A=90^\circ$ (Grazing incidence)

$n_B=\sqrt{ky^{3/2}+1}=\sqrt{y^{3/2}+1}$

because $k=1.0(\text{m})^{-3/2}$

$$\therefore (1)(1)=\sqrt{(y^{3/2}+1)}\sin i$$

$$\Rightarrow \sin i=\frac{1}{\sqrt{y^{3/2}+1}}$$

$$\therefore \cot i=\sqrt{y^{3/2}} \text{ or } y^{3/4} \qquad \ldots(ii)$$

Equating Eqs. (*i*) and (*ii*), we get

$$\frac{dy}{dx}=y^{3/4}$$

or $y^{-3/4}dy=dx$

or $\int_0^y y^{-3/4}dy=\int_0^x dx$

The required equation of trajectory is

or $4y^{1/4}=x$ ...(*iii*)

(*c*) At point P, where the ray emerges from the slab

$y=1.0$ m

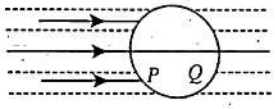
$\therefore x=4.0$ m [From Eq. (*iii*)]

Therefore, coordinates of point P are $P=(4.0\text{ m},1.0\text{ m})$

(*d*) As $n_A\sin i_A=n_P\sin i_P$ and as $n_A=n_P=1$

Therefore, $i_P=i_A=90^\circ$ i.e. the ray will emerge parallel to the boundary at P i.e. at grazing emergence.

42. (*a*)



Applying $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$, one by one on two spherical surfaces.

First on left surface

@FAKE_CBSE_@RAJ_EDUNET

$\frac{1}{v_1}-\frac{4/3}{\infty}=\frac{1-4/3}{+2}$ or $\frac{1}{v_1}=-\frac{1}{6}$

or $v_1=-6$ mm

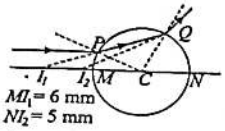
i.e. first image will be formed at 6 mm towards left of P

Second on right surface Now, distance of first image I_1 from Q will be 10 mm (towards left).

$\frac{4/3}{v_2}-\frac{1}{-10}=\frac{4/3-1}{-2}$

or $\frac{4}{3v_2}=-\frac{1}{6}-\frac{1}{10}=-\frac{4}{15}$ or $v_2=-5$ mm

(*b*) The ray diagram is shown in figure.



43. (*a*) Image of object will coincide with it if ray of light after refraction from the concave surface fall normally on concave mirror so formed by silvering the convex surface. or image after refraction from concave surface should form at centre of curvature of concave mirror or at a distance of 20 cm on same side of the combination. Let x be the distance of pin from the given optical system.

Applying, $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$

With proper signs, $\frac{1.5}{-20}-\frac{1}{-x}=\frac{1.5-1}{-60}$

or $\frac{1}{x}=\frac{3}{40}-\frac{1}{120}=\frac{8}{120}$

$\Rightarrow x=\frac{120}{8}=15$ cm

(*b*) Now, before striking with the concave surface, the ray is first refracted from a plane surface. So, let x be the distance of pin, then the plane surface will form its image at a distance $\frac{4}{3}x(h_{app.}=\mu h)Z$ from it.

Now, using $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$ with proper signs,

we have $\frac{1.5}{-20}-\frac{4/3}{-\frac{4x}{3}}=\frac{1.5-4/3}{-60}$

or $\frac{1}{x}=\frac{3}{40}-\frac{1}{360}$ or $x=13.84$ cm

$\Delta x=x_1-x_2=15$ cm -13.84 cm

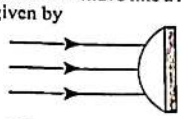
$=1.16$ cm (downwards)

44. (*a*) $\frac{1}{f}=(\mu-1)\frac{1}{R_1}-\frac{1}{R_2}$

$=(1.5-1)\frac{1}{12}-\frac{1}{\infty}=\frac{1}{24}$

$\therefore f=+24$ cm

(*b*) The system will behave like a mirror of power given by



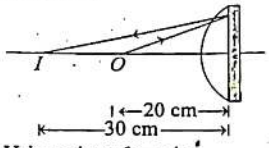
$P=2P_L+P_M$

$\therefore -\frac{1}{F(\text{m})}=2\frac{1}{0.24}+0$

$F=-0.12$ m $=-12$ cm

Hence, the system will behave like a concave mirror of focal length 12 cm. Therefore parallel rays will converge at a distance of 12 cm (to the left) of the system.

(*c*)



(*d*) Using mirror formula

$\frac{1}{v}+\frac{1}{-20}=\frac{-1}{12}$

Solving, we get $v=-30$ cm.

Therefore the image will be formed at a distance of 30 cm to the left of system.

45. (*d*) (1) If two structures have the same cross-sectional area but differing numerical apertures (NA_1 and NA_2 respectively), $\sin i_m=n_1\sin(90°-\theta_c)$

$\Rightarrow \sin i_m=n_1\cos\theta_c$

$\Rightarrow N_A=n_1\sqrt{1-sin^2\theta_c}$

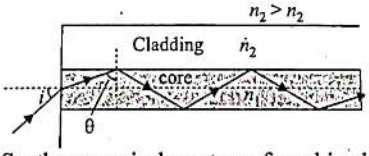
$=n_1\sqrt{1-\frac{n_2^2}{n_1^2}}$

$=\sqrt{n_1^2-n_2^2}$

On putting the values we have,

$NA_1=\frac{3}{4}$ and $NA_2=\frac{\sqrt{15}}{5}=\sqrt{\frac{3}{4}}$

$NA_2<NA_1$

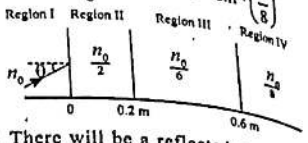


So, the numerical aperture of combined structure is less than the two numerical aperture, which is NA_2

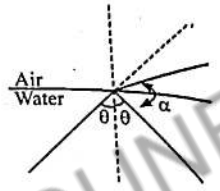
46. (*b*) Total internal reflection occurs at the interface of region III and IV as shown in figure.

$n_0\sin\theta=\frac{n_0}{2}\sin\theta_1=\frac{n_0}{6}\sin\theta_2=\frac{n_0}{8}\sin r$

$n_0\sin\theta=\frac{n_0}{8}\sin 90° \Rightarrow \theta=\sin^{-1}\left(\frac{1}{8}\right)$



47. (*c*) There will be a reflected ray and a refracted ray. Since incident angle is less than critical angle. Angle between two resultant rays would be between $180°-20°$



48. (*a*) Rays come out only from CD, means rays after refraction from AB get total internally reflected at AD.

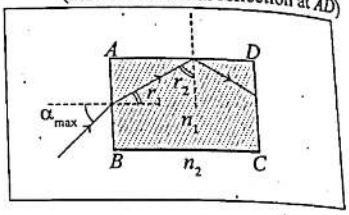
From the figure

$r_1+r_2+=90°$

$\therefore r_1=90°-r_2$

$(r_1)_{max}=90°-(r_2)_{min}$ and $(r_2)_{min}=\theta_c$

(for total internal reflection at AD)



where, $\sin\theta_c=\frac{n_2}{n_1}$

or $\theta_c=\sin^{-1}\left(\frac{n_2}{n_1}\right)$

$\therefore (r_1)_{max}=90°-\theta_c$

Now, applying Snell's law on face AB

$\frac{n_1}{n_2}=\frac{\sin\alpha_{max}}{\sin(r_1)_{max}}$

$=\frac{\sin\alpha_{max}}{\sin(90°-\theta_c)}=\frac{\sin\alpha_{max}}{\cos\theta_c}$

or $\sin\alpha_{max}=\frac{n_1}{n_2}\cos\theta_c$

$\therefore \alpha_{max}=\sin^{-1}\left[\frac{n_1}{n_2}\cos\theta_c\right]$

$=\sin^{-1}\left[\frac{n_1}{n_2}\cos\theta_c\right]$

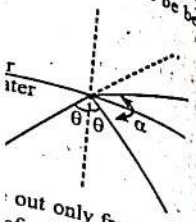
@TAKE_CBSE_TO_RAJ_PUNET

$= \frac{n_0}{8}\sin 90° \Rightarrow \theta = \sin^{-1}\left(\frac{1}{8}\right)$

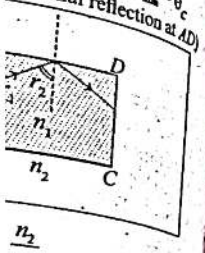
Region II $\frac{n_0}{2}$ Region III $\frac{n_0}{c}$ Region I n_1

0.2 m 0.6 m

vill be a reflected ray and a
d ray. Since incident angle is
critical angle. Angle between
ltant rays would be between
9°



out only from CD, means
efraction from AB get total
flected at AD.
ure
0°
$-r_2$
$-(r_2)_{min}$ and $(r_2)_{min} = \theta_c$
internal reflection at AD)



$\frac{n_2}{n_1}$

$\frac{1}{2}$

$-\theta_c$

Snell's law on face AB

$= \frac{\sin\alpha_{max}}{\cos\theta_c}$

$\cos\theta_c$

$\sin\theta_c$

49. *(a,c)* If you place the entire structure in a medium with a refractive index of n,
$n\sin i = n_1\sin(90-\theta)$ $n_1\sin(90-1)$
for (A)

$\frac{4}{3}\sin i = \frac{\sqrt{45}}{4}\sin(90-\theta_c) = \frac{\sqrt{45}}{4}\cos\theta_c$

$\sin\theta_c = \frac{n_2}{n_1}$

$\therefore \cos\theta = \sqrt{1-\left(\frac{n_2}{n_1}\right)^2}$

$\frac{4}{3}\sin i = \frac{\sqrt{45}}{4}\frac{3}{\sqrt{45}}$ $\sin i = \frac{9}{16}$

In second case, $\sin\theta_c = \frac{n_2}{n_1} = \frac{7}{8}$

$= \frac{8}{5}\sin(90-\theta_c)$

Simplifying we get, $\sin i = \frac{9}{16}$

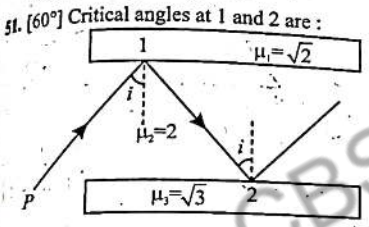
Same approach can be adopted for other options.

50. *(c,d)* For total internal reflection to take place Angle of incidence, $i >$ critical angle, θ_c
or $\sin i > \sin\theta_c$ or $\sin 45° > 1/n$

or $\frac{1}{\sqrt{2}} > \frac{1}{n}$ or $n > \sqrt{2}$ or $n > 1.414$

Therefore, possible values of n can be 1.5 or 1.6 in the given options.

51. [60°] Critical angles at 1 and 2 are :



$\theta_{c_1} = \sin^{-1}\frac{\mu_1}{\mu_2} = \sin^{-1}\frac{1}{\sqrt{2}} = 45°$

$\theta_{c_2} = \sin^{-1}\frac{\mu_3}{\mu_2} = \sin^{-1}\frac{\sqrt{3}}{2} = 60°$

Therefore, minimum angle of incidence for total internal reflection to take place on both slabs should be 60°.

$i_{min} = 60°$

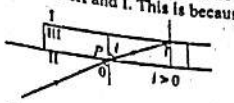
52. Given θ is slightly greater than $\sin^{-1}\frac{n_1}{n_2}$

(a) When $n_3 < n_1$
i.e $n_3 < n_1 < n_2$

or $\frac{n_3}{n_2} < \frac{n_1}{n_2}$ or $\sin^{-1}\frac{n_3}{n_2} < \sin^{-1}\frac{n_1}{n_2}$

Hence, critical angle for III and II will be less than the critical angle for II and I. So, if TIR is taking place between I and II, then TIR will definitely take place between I and III.

(b) When $n_3 > n_1$ Now two cases may arise :
Case 1 $n_1 < n_3 < n_2$
In this case there will be no TIR between II and III but TIR will take place between III and I. This is because



Ray of light first enters from II to III *i.e*, from denser to rarer.
$\therefore i > \theta$
Applying Snell's law at P

$n_2\sin\theta = n_3\sin i$ or $\sin i = \frac{n_2}{n_3}\sin\theta$

Since, $\sin\theta$ is slightly greater than $\frac{n_1}{n_2}$.

$\therefore \sin i$ is slightly greater than $\frac{n_2}{n_3}\times\frac{n_1}{n_2}$

or $\frac{n_1}{n_3}$

but $\frac{n_1}{n_3}$ is nothing but $\sin(\theta_c)_{I,III}$

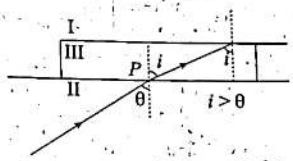
$\therefore \sin(i)$ is slightly greater than $\sin(\theta_c)_{I,III}$

Or TIR will now take place on I and III and the ray will be reflected back

Case-2 $2n_1 < n_2 < n_3$
This time while moving from II to III, ray of light will bend towards normal.
Again applying Snell's law at P

$n_2\sin\theta = n_3\sin i$

$\Rightarrow \sin i = \frac{n_2}{n_3}\sin\theta$



Since, $\sin\theta$ slightly greater than $\frac{n_1}{n_2}$

$\therefore \sin i$, will be slightly greater than

$\frac{n_2}{n_3}\times\frac{n_1}{n_2}$ or $\frac{n_1}{n_3}$

but $\frac{n_1}{n_3}$ is $\sin(\theta_c)_{I,III}$

i.e. $\sin i > \sin(\theta_c)_{I,III}$ or $i > (\theta_c)_{I,III}$
Therefore, TIR will again take place between I and III and the ray will be reflected back.

53. *(a)* From the geometry we have $r_1 + r_2 = 60°$
Using Snell's law at the left side we have $\frac{\sin 60°}{\sin r_1} = n$

or $\sin r_1 = \frac{\sqrt{3}}{2n}$

Using Snell's law at the right end
$\frac{\sin r_2}{\sin\theta} = \frac{1}{n}$
or $\sin\theta = n\sin r_2$
$n \times \sin(60° - r_1)$

$= n\left(\frac{\sqrt{3}}{2}\cos r_1 - \frac{1}{2}\sin r_1\right)$

$= n\left(\frac{\sqrt{3}}{2}\sqrt{1-\sin^2 r_1} - \frac{1}{2}\sin r_1\right)$

$= n\left(\frac{\sqrt{3}}{2}\sqrt{1-\frac{3}{4n^2}} - \frac{1}{2}\frac{\sqrt{3}}{2n}\right)$

Solving we get

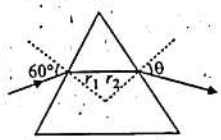
$\sin\theta = \frac{\sqrt{3}}{4}\sqrt{4n^2-3} - \frac{\sqrt{3}}{4}$

Differentiating

$\cos\theta d\theta = \frac{\sqrt{3}}{4}\times\frac{1}{2\sqrt{4n^2-3}}\times 8ndn$

or $\frac{d\theta}{dn} = \frac{\sqrt{3}n}{\sqrt{4n^2-3}}\times\frac{1}{\cos\theta}$

$= \frac{\sqrt{3}\times\sqrt{3}}{\sqrt{4\times 3-3}}\times\frac{1}{1/2} = 2$



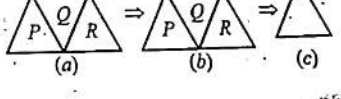
54. *(a)* During minimum deviation,

$r_1 = r_2 = \frac{A}{2} \Rightarrow r_1 = r_2 = 30°$

So, Angle of refraction is independent of the colour and 30° for both the colors.

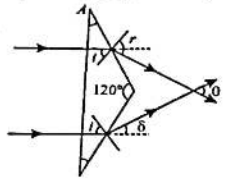
55. *(b)* During minimum deviation the ray inside the prism is parallel to the base of the prism in case of an equilateral prism.

56. *(c)* Figure *(a)* is part of an equilateral prism of figure *(b)* as shown in figure which is a magnified image of figure *(c)*. Therefore, the ray will suffer the same deviation in figure *(a)* and figure *(c)*.



@FAKE_CBSE_PORTAL_EDUNET

57. (*c*) The diagramatic representation of the given problem is shown in figure.



From figure it follows that $\angle i = \angle A = 30°$

From Snell's law, $n_1 \sin i = n_2 \sin r$

or $\sin r = \dfrac{1.44 \sin 30°}{1} = 0.72$

Now, $\angle\delta = \angle r - \angle i = \sin^{-1}(0.72) - 30°$

$\therefore \theta = 2\angle\delta) = 2\{\sin^{-1}(0.72) - 30°\}$

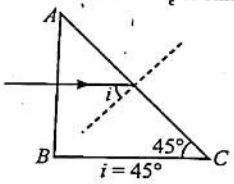
58. (*c*) Deviation $\delta = (\mu - 1)A$

Given, $\delta_{net} = 0$

$\therefore (\mu_1 - 1)A_1 = (\mu_2 - 1)A_2$

or $A_2 = \dfrac{(\mu_1 - 1)}{(\mu_2 - 1)} A_1 = \dfrac{(1.54 - 1)}{(1.72 - 1)}(4°) = 3°$

59. (*a*) The colours for which $i > \theta_c$, will get total internal reflection : $i > \theta_c$ or $\sin i > \sin\theta_c$



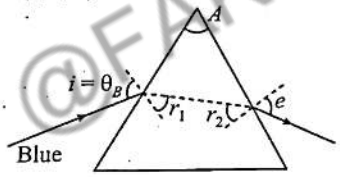
or $\sin 45° > \dfrac{1}{\mu}$ or $\dfrac{1}{\sqrt{2}} > \dfrac{1}{\mu}$

or for which $\mu > \sqrt{2}$ or $\mu = 1.414$

Hence, the rays for which $\mu = 1.414$ will get TIR.

For green and blue $\mu = 1.414$, so they will suffer TIR on face AC. Only red comes out from this face.

60. (*a, c, d*)



For blue light.

$\mu_B = \sqrt{3}$

$i = \theta_B = \tan^{-1}(\mu_B) = \tan^{-1}(\sqrt{3})$

$= \tan^{-1}(\tan 60°) = 60°$

Applying Snell's law, on first interface

$1 \sin 60° = \sqrt{3} \sin r_1 \Rightarrow r_1 = 30°$

$\because r_1 + r_2 = A \Rightarrow r_2 = A - 30°$

Since, $\delta = (i + e) - A$

$\therefore 60° = 60° + e - A \Rightarrow e = A$

Applying Snell's law on second interface,

$\sqrt{3} \sin r_2 = 1 \sin e$

$\sqrt{3} \sin(A - 30) = \sin A$

On solving, we get

$A = 60°$

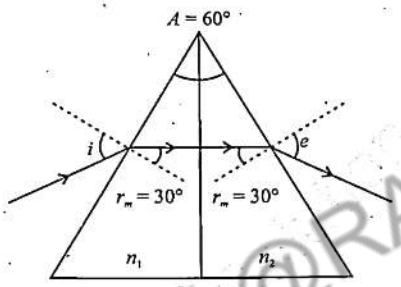
$\therefore e = 60°$

For red light, prism formula of refractive index.

$$\mu = \frac{\sin\left(\dfrac{A + \delta_{min}}{2}\right)}{\sin\dfrac{A}{2}}$$

$$= \frac{\sin\left(\dfrac{60° + 30°}{2}\right)}{\sin\left(\dfrac{60°}{2}\right)} = \sqrt{2}$$

61. (*b, c*)



$n_1 = n_2 = n = \dfrac{3}{2}$ for minimum deviation.

$r_m = \dfrac{A}{2} = \dfrac{60}{2} = 30°$ and $i = e = \theta$

$$n = \frac{\sin\left(\dfrac{\delta_{min} + A}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$$

$$\Rightarrow \frac{3}{2} = \frac{\sin\theta}{\sin\left(\dfrac{60}{2}\right)}$$

$\Rightarrow \sin\theta = \dfrac{3}{4} \Rightarrow \cos\theta = \dfrac{\sqrt{7}}{4}$

If $n_1 = n = \dfrac{3}{2}$ and $n_2 = n + \Delta n$

$e = \theta + \Delta\theta$

(1) $\sin\theta = n \sin 30°$

$(n + \Delta n) \sin 30° = (1) \sin(\theta + \Delta\theta)$

$\dfrac{\Delta n}{\Delta\theta} = 1.34 > 1$

Solving $\dfrac{1}{2}(\Delta n) = \sin(\theta + \Delta\theta) - \sin\theta$

$$\frac{\Delta n}{2} = \frac{\sin(0 + \Delta 0) - \sin 0}{\Delta 0} \times \Delta 0$$

$$\frac{d(\sin\theta)}{d\theta} = \cos\theta$$

$$\frac{\Delta n}{2} = (\cos 0)(\Delta 0) \Rightarrow \frac{\Delta n}{2} = \frac{\sqrt{7}}{4}(\Delta 0)$$

$$\Rightarrow \frac{\sqrt{7}}{2} = \frac{2.64}{2}$$

$\Rightarrow$ option (*a*) is incorrect.

$\Delta n = (1.34)\Delta 0$

$\Rightarrow \Delta 0 \propto \Delta n \Rightarrow$ option (b) is correct.

$$\frac{\Delta n}{\Delta\theta} = \frac{\sqrt{7}}{2} \Rightarrow \frac{2.8 \times 10^{-3}}{\Delta\theta} = \frac{\sqrt{7}}{2}$$

$$\Delta\theta = \frac{5.6 \times 10^{-3}}{\sqrt{7}} = \sqrt{7} \times 0.8 \times 10^{-3}$$

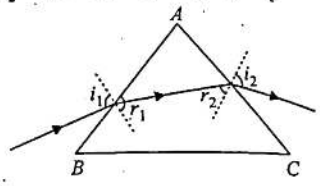
$\Delta\theta = (2.64 \times 0.8) \times 10^{-3} = 2.11 \times 10^{-3}$ rad

So, option (*c*) is correct.

62. (*a,c,d*) The smallest divergence that a prism can make.

When the emergent ray at the second surface is tangential to the surface of this prism

$i_2 = \pi/2 \Rightarrow r_2 = \theta_c \Rightarrow r_1 = A - \theta_c$



so, $\sin i_1 = \mu \sin(A - \theta_c)$

so, $i_1 = \sin^{-1}\left[\sin A \sqrt{4\cos^2\dfrac{A}{2} - 1} - \cos A\right]$

For minimum deviation through isosceles prism, the ray inside the prism is parallel to the base of the prism if $\angle B = \angle C$.

But it is not necessarily parallel to the base if,

$\angle A = \angle B$ or $\angle A = \angle C$

Hence option *a, c, d* is correct

63. (*a,b,c*) The ray *OP* runs parallel to the BC side.

As a result, the angle of incidence of this light on *CD* becomes

When Snell's Law is applied to the point *Q*,

$\sqrt{2} \sin 45° = \sin r > 1$

As a result, this is an instance of complete internal reflection.

As a result, the angle of incidence and the angle of reflection are equal.

On side *AD*, this creates an angle of incidence.

@FAKE_CBSE_X @RAJEDUNET

$\frac{\Delta\theta) - \sin\theta}{\Delta\theta} \times \Delta\theta$

$= \cos\theta$

$\theta)(\Delta\theta) \Rightarrow \frac{\Delta n}{2} = \frac{\sqrt{7}}{4}(4\theta)$

$\frac{2.64}{2}$

(a) is incorrect.

$\Delta\theta$

$n \Rightarrow$ option (b) is correct.

$\frac{2.8\times10^{-3}}{\Delta\theta} = \frac{\sqrt{7}}{2}$

$^{-3}$

$= \sqrt{7}\times0.8\times10^{-3}$

$\times0.8)\times10^{-3} = 2.11\times10^{-3}$ rad

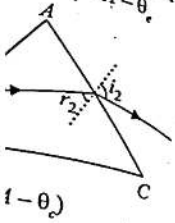
is correct.

allest divergence that a prism

gent ray at the second surface

the surface of this prism

$\theta_e \Rightarrow r_1 = A - \theta_e$



$1-\theta_c)$

$A\sqrt{4\cos^2\frac{A}{2}-1}-\cos A$

riation through isosceles

le the prism is parallel to

m if $\angle B = \angle C$.

ssarily parallel to the

$\angle C$

l is correct

runs parallel to the BC

le of incidence of this

applied to the point Q.

instance of complete

of incidence and the

equal.

eates an angle of

According to Snell's Law,

$\sqrt{3}\sin30° = \sin r = \frac{\sqrt{3}}{2}$

$\Rightarrow r = 60°$

Thus the angle between rays OP and RS is 90°

(d) For $e \to i$

$\Rightarrow 45° > \theta_c \Rightarrow \sin45° > \sin\theta_c$

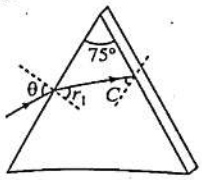
$\Rightarrow \frac{1}{\sqrt{2}} > \frac{\mu_2}{\mu_1} \Rightarrow \mu_1 > \sqrt{2}\mu_2$

For $e \to f$ angle of refraction is less than angle of incidence, so $\mu_2 > \mu_1$ and then $\mu_2 > \mu_3$

For $e \to g$, $\mu_1 = \mu_2$ for $e \to h$, $\mu_2 < \mu_1 < \sqrt{2}\mu_2$ and $\mu_2 > \mu_3$

65. [1.50]

At $\theta = 60°$ ray incidents at critical angle at second surface



So, $1 \times \sin 60° = \sqrt{3}\ \sin r_1$

$\frac{\sqrt{3}}{2} = \sqrt{3}\ \sin r_1$

$r_1 = 30°$

$r_2 = 45° = C \quad (\because r_1 + r_2 = A)$

Aslo, $\sqrt{3}\ \sin 45° = n \sin 90°$

$n = \sqrt{\frac{3}{2}} \Rightarrow n^2 = \frac{3}{2}$

66. [$\sqrt{3}$] Given $i_1 = 60°$, $A = 30°$, $\delta = 30°$

From the relation

$\delta = (i_1 + i_2) - A$

we have, $i_2 = 0°$

i.e. the ray is perpendicular to the face from which it emerges.

Further, $i_2 = 0°$

$\therefore r_2 = 0°$

$r_1 + r_2 = A$

$r_1 = A = 30°$

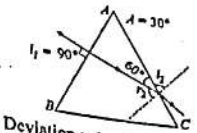
$\mu = \frac{\sin i_1}{\sin r_1} = \frac{\sin 60°}{\sin 30°} = \sqrt{3}$

67. Ray falls normally on the face AB. Therefore, it will pass undeviated through AB.

$\therefore r_2 = 90° - 60° = 30°$

$\mu = \sqrt{2} = \frac{\sin i_2}{\sin r_2}$

$i_2 = 45°$



Deviation $= i_2 - r_2 = 45° - 30° = 15°$

(Deviation at face AC only)

68. Let δ_m be the angle of minimum deviation. Then

$\mu = \frac{\sin\frac{A+\delta_m}{2}}{\sin(A/2)}$

($A = 60°$ for an equilateral prism)

$\therefore \sqrt{2} = \frac{\sin\frac{60°+\delta_m}{2}}{\sin\frac{60°}{2}}$

Solving this we get $\delta_m = 30°$

The given deviation is also 30° (i.e. δ_m)

Under minimum deviation, the ray inside the prism is parallel to base for an equilateral prism.

69. [True] Through a thin glass slab ray of light almost passes undeviated. A hollow prism can be assumed to be made up of three thin glass slabs as shown in figure.

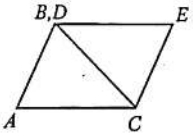
70. (a) At minimum deviation, $r_1 = r_2 = 30°$

$\therefore$ From Snell's law

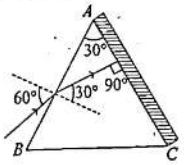
$\mu = \frac{\sin i_1}{\sin r_1}$ or $\sqrt{3} = \frac{\sin i_1}{\sin 30°}$

$\therefore \sin i_1 = \frac{\sqrt{3}}{2}$ or $i_1 = 60°$

(b) In the position shown net deviation suffered by the ray of light should be minimum. Therefore, the second prism should be rotated by 60° (anti-clockwise).



71. (a) $\sin i_1 = \mu \sin r_1$



or $\sin 60° = \sqrt{3}\sin r_1$

$\therefore \sin r_1 = \frac{1}{2}$ or $r_1 = 30°$

Now, $r_1 + r_2 = A$

$\therefore r_2 = A - r_1 = 30° - 30° = 0°$

Therefore, ray of light falls normally on the face AC and angle of emergence $i_2 = 0°$.

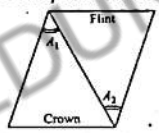
(b) Multiple reflections occur between surface of film. Intensity will be maximum if constructive interference takes place in the transmitted wave.

For maximum thickness

$\Delta x = 2\mu t = \lambda$ (t = thickness)

$\therefore t = \frac{\lambda}{2\mu} = \frac{6600}{2\times2.2} = 1500\text{Å}$

72. (a) When angle of prism is small and angle of incidence is also small, the deviation is given by $\delta = (\mu - 1)A$. Net deviation by the two prisms is zero. So,



or $(\mu - 1)A_1 + (\mu_2 - 1)A_2 = 0$

Here, μ_1 and μ_2 are the refractive indices for crown and flint glasses respectively.

Hence,

$\mu_1 = \frac{1.51+1.49}{2} = 1.5$ and

$\mu_2 = \frac{1.77+1.73}{2} = 1.75$

A_1 = Angle of prism for crown glass = 6°

Substituting the values in Eq. (i), we get

$(1.5 - 1)(6°) + (1.75 - 1)A_2 = 0$

This gives $A_2 = -4°$

Hence, angle of flint glass prism is 4° (Negative sign shows that flint glass prism is inverted with respect to the crown glass prism.)

(b) Net dispersion due to the two prisms is

$= (\mu_{b_1} - \mu_{r_1})A_1 + (\mu_{b_2} - \mu_{r_2})A_2$

$= (1.51 - 1.49)(6°) + (1.77 - 1.73)(-4°) = -0.04°$

$\therefore$ Net dispersion is –0.04°

73. (a) $n_1 = 1.20 + \frac{10.8\times10^4}{\lambda^2}$ and

$n_2 = 1.45 + \frac{1.80\times10^4}{\lambda^2}$

Here, λ is in nm.

The incident ray will not deviate at BC if $n_1 = n_2$:

$\Rightarrow 1.20 + \frac{10.8\times10^4}{\lambda_0^2} = 1.45 + \frac{1.80\times10^4}{\lambda_0^2}$

@FREE_CBSE_X@RD_EDUSET

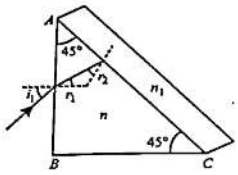
$\Rightarrow \frac{9\times10^4}{\lambda_0^2}=0.25$

or $\lambda_0=\frac{3\times10^2}{0.5}$ or $\lambda_0=600$ nm

(*b*) The given system is a part of an equilateral prism of prism angle 60° as shown in given figure.

74. (*a*) Critical angle θ_c at face AC will be given by

$\theta_c=\sin^{-1}\frac{n_1}{n}$ or $\sin\theta_c=\frac{n_1}{n}$



Now, it is given that $r_2=\theta_c$

$r_1=A-r_2=(45°-\theta_c)$

Applying Snell's law at face AB, we have

$n=\frac{\sin i_1}{\sin r_1}$ or $\sin i_1=n\sin r_1$

$\therefore\ i_1=\sin^{-1}(n\sin r_1)$

Substituting value of r_1, we get

$i_1=\sin^{-1}\{n\sin(45°-\theta_c)\}$

$\sin^{-1}\{n(\sin45°\cos\theta_c-\cos45°\sin\theta_c)\}$

$=\sin^{-1}\frac{n}{\sqrt2}\left(\sqrt{1-\sin^2\theta_c}-\sin\theta_c\right)$

$=\sin^{-1}\frac{n}{\sqrt2}\sqrt{1-\frac{n_1^2}{n^2}}-\frac{n_1}{n}$

$i_1=\sin^{-1}\frac{1}{\sqrt2}\left(\sqrt{n^2-n_1^2}-n_1\right)$

Therefore, required angle of incidence (i_1) at face AB for which the ray strikes at AC at critical angle is

$i_1=\sin^{-1}\frac{1}{\sqrt2}(\sqrt{n^2-n_1^2}-n_1)$

(*b*) The ray will pass undeviated through face AC when either $n_1=n$ or $r_2=0°$ i.e. ray falls normally on face AC.

Here $n_1\neq n$ (because $n_1<n$ is given)

$\therefore\ r_2=0°$

or $r_1=A-r_2=45°-0°=45°$

Now applying Snell's law at face AB,

we have $n=\frac{\sin i_1}{\sin r_1}$ or $1.352=\frac{\sin i_1}{\sin45°}$

$\therefore \sin i_1=(1.352)\frac{1}{\sqrt2}$,

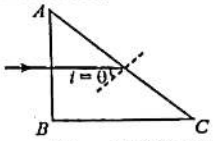
$\therefore\ \sin i_1=0.956$

$i_1=\sin^{-1}(0.956)\approx73°$

Therefore, required angle of incidence is $i=73°$

75. (*a*) Total internal reflection (TIR) will take place first for that wavelength for which critical angle is small or μ is large.

From the given expression of μ, it is more for the wavelength for which value of λ is less.



Thus, condition of TIR is just satisfied for 4000Å.

or $i=\theta_C$ for 4000Å or $\theta=\theta$

or $\sin\theta=\sin\theta_c$

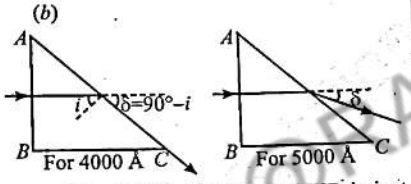
or $0.8=\frac{1}{\mu}$ (for 4000Å)

or $0.8=\frac{1}{1.20+\frac{b}{(4000)^2}}$

Solving this equation, we get

$b=8.0\times10^5(\text{Å})^2$

(*b*)



For, 4000Å condition of TIR is just satisfied. Hence, it will emerge from AC, just grazingly.

or $\delta_{4000Å}=90°-i=90°-\sin^{-1}(0.8)\approx37°$

For 5000Å $\mu=1.2+\frac{b}{\lambda^2}$

$=1.2+\frac{8.0\times10^5}{(5000)^2}=1.232$

Applying $\mu=\frac{\sin i_{air}}{\sin i_{medium}}$

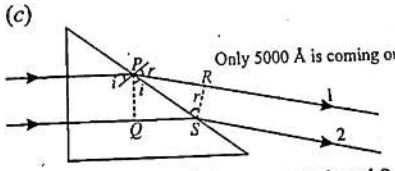
or $1.232=\frac{\sin i_{air}}{\sin\theta}=\frac{\sin i_{air}}{0.8}$

$\Rightarrow i_{air}=80.26°$

$\therefore\ \delta_{5000A}=i_{air}-i_{medium}$

$=80.26°-\sin^{-1}(0.8)=27.13°$

(*c*)



Path difference between rays 1 and 2

$\Delta x=\mu(QS)-PR$ ...(*i*)

Further, $\frac{QS}{PS}=\sin i\Rightarrow\frac{PR}{PS}=\sin r$

$\therefore\ \frac{PR/PS}{QS/PS}=\frac{\sin r}{\sin i}=\mu\Rightarrow\mu(QS)=PR$

Substituting in Eq. (*i*), we get $\Delta x=0$

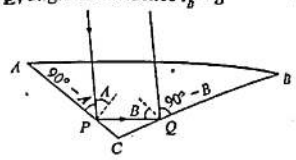
$\therefore$ Phase difference between rays 1 and 2 will be zero.

Or these two rays will interfere constructively. So, maximum intensity will be obtained from their interference.

or $I_{max}=(\sqrt{I_1}+\sqrt{I_2})^2$

$=(\sqrt{4I}+\sqrt{I})^2=9I$

76. (*a*) At P, angle of incidence $i_A=A$ and at Q, angle of incidence $i_B=B$



If condition of TIR is satisfied for the smaller angle of incidence than for larger angle of incidence it automatically satisfied.

$B\leq A\ \therefore\ i_B\leq i_A$

Let us take $B=30°$ and $A=60°$, then to satisfy condition of TIR on both points P and Q.

$\sin\theta_c\leq\sin30°$ or $\frac{1}{\mu}\leq\frac{1}{2}$ or $\mu\geq2$

Now, let us take $B=37°$ and $A=53°$.

Then

$\sin\theta_c\leq\sin37°$ or $\frac{1}{\mu}\leq\frac{3}{5}$ or $\mu\geq\frac{5}{3}$ or 1.67

So, as B in increasing desired value of μ is decreasing.

Maximum value of B for the condition $B\leq A$ is 45°.

For that $\mu\geq\sqrt2$.

(*b*) For $\mu=\frac{5}{3}$, $\sin\theta_c=\frac{1}{\mu}=\sin^{-1}\frac{3}{5}\approx37°$

If $B=30°$, then $i_B=30°$

then $A=60°$ or $i_A=60°$

$i_A>\theta_c$ but $i_B<\theta_c$

i.e. TIR will take place at A but not at B.

or we write : $\sin i_B<\sin\theta_c<\sin i_A$

or $\sin30°<\frac{3}{5}<\sin60°$

or $0.5<0.6<0.86$

77. (*b*) Focal length of convex lens f_1,

Therefore $\frac{1}{f_1}=(1-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$

$=(1.5-1)\left[\frac{1}{20}-\left(\frac{1}{-20}\right)\right]$

$\Rightarrow f_1=+20$ cm

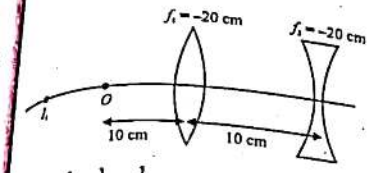
Focal length of concave lens f_2,

@TARE CBSE TOPPAJ BHUNET

$$\therefore \frac{1}{f_2} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{f_2} = (1.5-1)\left[-\frac{1}{20} - \frac{1}{20}\right] = \frac{1}{-20}$$

$$\Rightarrow f_2 = -20 \text{ cm}$$



$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\Rightarrow v = -20 \text{ cm}$$

$$m_1 = \frac{v}{u} = \frac{-20}{-10} = 2$$

For lens 2

$u = -30n$ cm, $f = -20$ cm,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

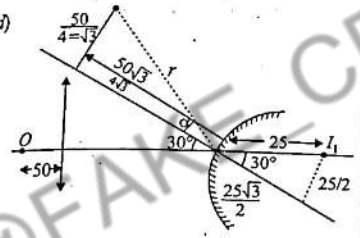
$$v = -12 \text{ cm}$$

$$m_2 = \frac{v}{u} = \frac{-12}{-30} = \frac{2}{5}$$

Net magnification,

$$m = m_1 m_2 = 2 \times \frac{2}{5} = \frac{4}{5} = 0.8$$

78. (d)



In the case of Lens

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow v = \frac{uf}{u+f}$$

$$\Rightarrow v = \frac{(-50)(30)}{-50+30} = 75 \text{ cm}$$

In the case of Mirror

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow v = \frac{uf}{u-f}$$

$$\Rightarrow v = \frac{\left(\frac{25\sqrt{3}}{2}\right)(50)}{\frac{25\sqrt{3}}{2} - 50} = \frac{-50\sqrt{3}}{4-\sqrt{3}}$$

$$\Rightarrow m = -\frac{v}{u} = \frac{h_2}{h_1}$$

$$\Rightarrow h_2 = -\left(\frac{\frac{-50\sqrt{3}}{4-\sqrt{3}}}{\frac{25\sqrt{3}}{2}}\right) \cdot \frac{25}{2}$$

$$\Rightarrow h_2 = \frac{+50}{4-\sqrt{3}} \text{ cm}$$

The coordinate of the images in x-direction $= 50 - \cos 30 + h_2 \cos 60 \approx 25$

The coordinate of the images in y-direction $= v \sin 30 + h_2 \sin 60 \approx 25\sqrt{3}$

79. (b) For S_1

$$\frac{\mu_1}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

Substituting the respective values we get,

$$\frac{1}{v} - \frac{1.5}{(1-50)} = \frac{1-1.5}{-10}$$

or $\frac{1}{v} + \frac{3}{100} = \frac{1}{20}$

$V = 50$ cm

This acts as image for S_2 with distance from it's aperture as $d - 50$ cm

Given $v = \infty$, $u = -(d-50)$ cm,

$R = 10$ cm

$$\frac{\mu_2}{2} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$0 - \frac{1}{-(d-50)} = \frac{1.5-1}{10}$$

or $\frac{1}{d-50} = \frac{1}{20}$

$d = 70$ cm

80. (a) Here we have given

$$\frac{r}{R} = \frac{2}{20} = \frac{1}{10}$$

$$\therefore \text{ Ratio of area} = \left(\frac{r}{R}\right)^2 = \frac{1}{100}$$

Let energy incident on lense be E

$$\therefore \text{ Given } \frac{E}{A} = 1.3$$

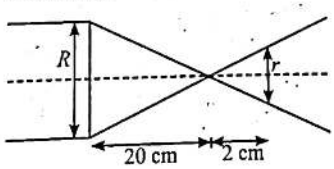
To calculate: final $\frac{E}{a}$

Also $\frac{a}{A} = \frac{1}{100}$

$\therefore$ Average intensity of light at

$$22 \text{ cm} = \frac{E}{a} = \frac{A \times 1.3}{a} = 100 \times 1.3$$

$$= 130 \text{ kW/m}^2$$



81. (c) Since the wavelength of light becomes $\frac{2}{3}$ times of the wavelength in free space, the refractive index of the material of lens is $\frac{3}{2} = 1.5$

Consider refraction from first surface,

$$\frac{1.5}{v_1} - \frac{1}{u} = \frac{1.5-1}{R}$$

For refraction from second surface,

$$\frac{1}{v_2} - \frac{1.5}{v_1} = \frac{1-1.5}{\infty}$$

Hence, $\frac{1}{v_2} - \frac{1}{u} = \frac{0.5}{R}$

Magnification of the lens is given by

$$M_1 \times M_2 = \frac{v_1}{u} \times \frac{v_2}{v_1} = \frac{v_2}{u} = \frac{-1}{3}$$

(negative since image is real)

It is given that $v_2 = 8$ m

$\Rightarrow u = -24$ m

Hence, $R = 3$ m

82. (b) Image after refraction from lens,

$$\frac{1}{v_1} - \frac{1}{-30} = \frac{1}{15}$$

$v_1 = 30$ cm

As a result, the image is 20 cm behind the mirror.

At 20 cm in front of the mirror, the mirror reflects the picture to form its own image. This image serves as a focal point for the lens.

$u_2 = 20 - 10 = 10$ cm

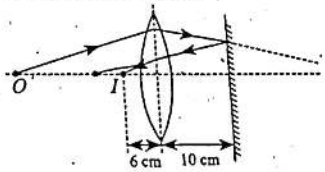
$$\frac{1}{v_2} - \frac{1}{u_2} = \frac{1}{f}$$

Thus $v_2 = 6$ cm

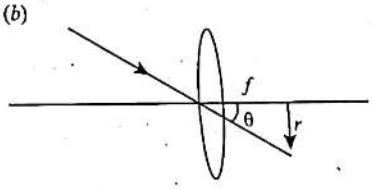
This is the distance of the image from the lens.

Therefore the distance of image from mirror

$= 6 \text{ cm} + 10 \text{ cm} = 16 \text{ cm}$



83. (b)



$r = f \tan\theta$ or $r \propto f$

$\therefore \pi r^2 \propto f^2$

@FAKE_CBSE_@RAJEBUNET

84. (*b*) From the lens formula,

$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ we have, $\frac{1}{f}=\frac{1}{10}-\frac{1}{-10}$

or $f=+5$

Further, $\Delta u = 0.1$ and $\Delta v = 0.1$

(from the graph)

Now, differentiating the lens formula, we have

$\frac{\Delta f}{f^2}=\frac{\Delta v}{v^2}+\frac{\Delta u}{u^2}$ or $\Delta f=\left(\frac{\Delta v}{v^2}+\frac{\Delta u}{u^2}\right)f^2$

Substituting the values, we have

$\Delta f=\frac{0.1}{10^2}+\frac{0.1}{10^2}(5)^2=0.05$

$\therefore\ f\pm\Delta f=5\pm0.05$

85. (*c*) Refraction from lens : $\frac{1}{v_1}-\frac{1}{-20}=\frac{1}{15}$

$\therefore\ v = 60$ cm + ve direction

i.e. first image is formed at 60 cm to the right of lens system.

Reflection from mirror

After reflection from the mirror, the second image will be formed at a distance of 60 cm to the left of lens system.

Refraction from lens

$\frac{1}{v_3}-\frac{1}{60}=\frac{1}{15}\leftarrow$ +ve direction

$v_3 = 12$cm

Therefore, the final image is formed at 12 cm to the left of the lens system.

86. (*d*) Let focal length of convex lens is $+f$, then focal length of concave lens would be $-\frac{3}{2}f$.

From the given condition,

$\therefore\ \frac{1}{30}=\frac{1}{f}-\frac{2}{3f}=\frac{1}{3f}$

$\therefore\ f = 10$ cm

Therefore, focal length of convex lens = +10 cm and that of concave lens = −15 cm

NOTE Since the combination is behaving like a convex lens (as F is positive).

Hence, power of convex lens is more or its focal length is less

87. (*a*) $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ ...(*i*)

$f = 0.3$

at given point of time given $u = -0.4$

$\therefore\ \frac{1}{v}=\frac{1}{0.3}-\frac{1}{0.4}=\frac{1}{1.2}$

$v = 1.2$

Differentiating 1 with respect to time

$\frac{-1}{v^2}\times\frac{dv}{dt}+\frac{1}{u^2}\times\frac{du}{dt}=0$ ...(*ii*)

Given $\frac{du}{dt}=0.01$ m/s

Putting the values of $u, v, \frac{du}{dt}$ in equation 2

$\frac{dv}{dt}=0.09$ m/s

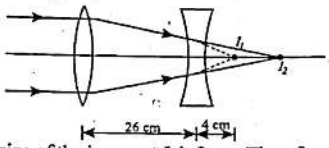
88. (*b*) Image formed by convex lens at I_1 will act as a virtual object for concave lens. For concave lens

$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$ or $\frac{1}{v}-\frac{1}{4}=\frac{1}{-20}$

or $v = 5$ cm

Magnification for concave lens

$m=\frac{v}{u}=\frac{5}{4}=1.25$



As size of the image at I_1 is 2 cm. Therefore, size of image at I_2 will be $2\times1.25=2.5$ cm.

89. (*d*) The lens makers' formula is

$\frac{1}{f}=\left(\frac{n_L}{n_m}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

where, n_L = Refractive index of lens and n_m = Refractive index of medium.

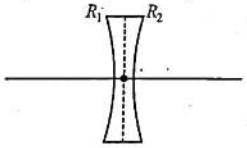
In case of double concave lens, R_1 is negative and R_2 is positive. Therefore, $\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ will be negative.

For the lens to be diverging in nature, focal length f should be negative or $\frac{n_L}{n_m}-1$ should be positive or $n_L > n_m$.

Since $n_2 > n_1$ (given), therefore the lens should be filled with L_2 and immersed in L_1.

90. (*a*) Locus of equal path difference are the lines running parallel to the axis of the cylinder. Hence, straight fringes are obtained.

91. (*a*) $R_1=-R, R_2=+R, \mu_g=1.5$ and $\mu_m=1.75$



$\therefore\ \frac{1}{f}=\left(\frac{\mu_g}{\mu_m}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

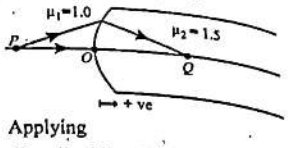
Substituting the values, we have

$\frac{1}{f}=\left(\frac{1.5}{1.75}-1\right)\left(\frac{1}{-R}-\frac{1}{R}\right)=\frac{1}{3.5R}$

$\therefore\ f=+3.5R$

Therefore, in the given medium it will behave like a convergent lens of focal length 3.5 R. It can be understood as, $\mu_m > \mu_g$, the lens will change its behaviour.

92. (*a*) Let us say $PO = OQ = X$



Applying

$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$

Substituting the values with sign

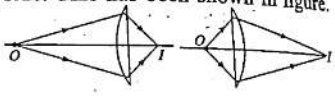
$\frac{1.5}{+X}-\frac{1.0}{-X}=\frac{1.5-1.0}{+R}$

(Distances are measured from O and are taken as positive in the direction of ray of light)

$\therefore\ \frac{2.5}{X}=\frac{0.5}{R}$

$\therefore\ X = 5R$

93. (*b*) In general spherical aberration is minimum when the total deviation produced by the system is equally divided on all refracting surfaces. A plano-convex lens is used for this purpose. In order that the total deviation be equally divided on two surfaces, it is essential that more parallel beam (or the incident and refracted) be incident on the convex side. Thus, when the object is far away from the lens, incident rays will be more parallel than the refracted rays, therefore, the object should face the convex side. On the other hand, if the object is near the lens, the object should face the plane side. This has been shown in figure.



94. (*b*) The focal length of combination is given by

$\frac{1}{F}=\frac{1}{40}-\frac{1}{25}$ $\left(\frac{1}{F}=\frac{1}{F_1}+\frac{1}{F_2}\right)$

or $F=-\frac{200}{3}$ cm $=-\frac{2}{3}$ m

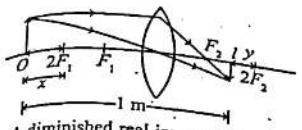
$\therefore$ Power of the combination in dioptres,

$P=-\frac{3}{2}$ $\left[P=\frac{1}{F(\text{m})}\right]$

$=-1.5$

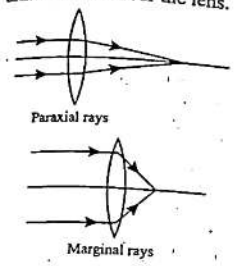
95. (*c*) Image can be formed on the screen if it is real. Real image of reduced size can be formed by a concave mirror or a convex lens.

@FAKE_CBSE_RAJ_DUNET

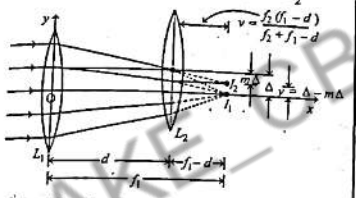


A diminished real image is formed by a convex lens when the object is placed beyond $2f$ and the image of such object is formed between f and $2f$ on other side.
Thus, $d > (2f + 2f)$ $(x > y)$
or $4f < 0.1$ m or $f < 0.25$ m

96. (c) Spherical aberration is caused due to spherical nature of lens. Paraxial and marginal rays are focused at different places on the axis of the lens. Therefore, image so formed is blurred. This aberration can be reduced by either stopping paraxial rays or marginal rays, which can be done by using a circular annular mark over the lens.



97. (c) From the first lens parallel beam of light is focused at its focus i.e. at a distance f_1 from it. This image I_1 acts as virtual object for second lens L_2. Therefore, for L_2



$u = +(f_1 - d), f = +f_2$

$$\therefore \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{f_2} + \frac{1}{f_1 - d}$$

Hence, $v = \dfrac{f_2(f_1 - d)}{f_2 + f_1 - d}$

Therefore, x-coordinate of its focal point will be

$$x = d + v = d + \frac{f_2(f_1 - d)}{f_2 + f_1 - d}$$

$$= \frac{f_1 f_2 + d(f_1 - d)}{f_1 + f_2 - d}$$

Linear magnification for L_2

$$m = \frac{v}{u} = \frac{f_2(f_1 - d)}{f_2 + f_1 - d} \cdot \frac{1}{f_1 - d}$$

$$= \frac{f_2}{f_2 + f_1 - d}$$

Therefore, second image will be formed at a distance of $m\Delta$ or $\dfrac{f_2}{f_2 + f_1 - d} \cdot \Delta$ below its optic axis.
Therefore, y-coordinate of the focus of system will be

$$y = \Delta - \frac{f_2\Delta}{f_2 + f_1 - d} \text{ or } y = \frac{(f_1 - d)\cdot\Delta}{f_2 + f_1 - d}$$

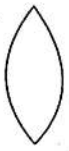
98. (a) $P = P_1 + P_2 = \dfrac{1}{f_1(\text{m})} + \dfrac{1}{f_2(\text{m})}$

$$= \frac{1}{0.4} - \frac{1}{0.25} = -1.5\text{D}$$

99. (a,c,d) When $n_1 = n_2 = n$

$$\frac{1}{f} = (n-1)\times\frac{2}{R}$$

So $f = \dfrac{R}{2(n-1)}$ ...(i)



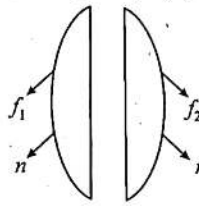
2nd case :

$$\frac{1}{f_1} = \frac{n-1}{R} \Rightarrow \frac{1}{f_2} = \frac{(n+\Delta n)-1}{R}$$

$$\frac{1}{f_{eq}} = \frac{1}{f+\Delta f} = \left(\frac{n-1}{R}\right) + \frac{(n+\Delta n)-1}{R}$$

$$= \frac{2(n-1)+\Delta n}{R}$$

$$\Delta f = \left(\frac{R}{2(n-1)+\Delta n}\right) - \left(\frac{R}{2(n-1)}\right)$$



$$= \frac{R}{2}\left[\frac{(n-1)-(n-1+\Delta n)}{(n-1+\Delta n)(n-1)}\right] = \frac{-\Delta n}{(n-1)} \times \frac{R}{2}$$

$$\frac{\Delta f}{f} = -\frac{\Delta n}{2(n-1)} \quad \text{...(ii)}$$

(a) Relation between $\dfrac{\Delta f}{f}$ and $\dfrac{\Delta n}{n}$ is independent of R so (a) is correct.

(b) $2n - 2 < n$ because $n < 2$

$$\Rightarrow \frac{\Delta f}{f} = \frac{1}{2}\left|\frac{\Delta n}{n-1}\right| > \frac{\Delta n}{n}$$

So $\dfrac{\Delta f}{f} > \left|\dfrac{\Delta n}{n}\right|$

So (b) is wrong

(c) $|\Delta f| = \dfrac{f\Delta n}{2(n-1)} = \dfrac{(20\times10^{-3})}{2(1.5-1)}$

$= 20 \times 10^{-3} = 0.02$ cm

So (c) is correct

(d) If $\dfrac{\Delta n}{n} < 0$ then $\dfrac{\Delta f}{f} > 0$ from equation (ii)

So (d) is correct

100. (c,d) $H_1 = \dfrac{2H}{3} = \dfrac{2}{3}\times\dfrac{3}{10} = \dfrac{1}{5}m$

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

for 2nd

$$\frac{1}{v_2} - \frac{1.5}{-0.3} = \frac{1-1.5}{-3}$$

$$\frac{1}{v_2} + 5 = \frac{1}{6}$$

$$\frac{1}{v_2} = \frac{1}{6} - 5 = \frac{-29}{6} \Rightarrow v_2 = -\frac{5}{29}$$

$$H_2 = \frac{6}{29} \Rightarrow H_2 > H_1$$

For 3rd

$$\frac{1}{v_3} - \frac{1.5}{-0.3} = \frac{1-1.5}{3} \Rightarrow \frac{1}{v_3} + 5 = -\frac{1}{6}$$

$$\frac{1}{v_3} = -\frac{1}{6} - 5 = -\frac{31}{6}$$

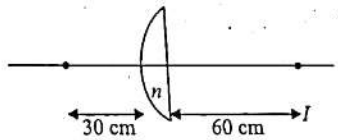
$$v_3 = -\frac{6}{31}, H_3 = \frac{6}{31}$$

So

$H_3 < H_1 < H_2$ and $(H_2 - H_3)$

$$= \frac{6}{29} - \frac{6}{31} = 0.68 \text{ cm}$$

101. (a, d) Case 1

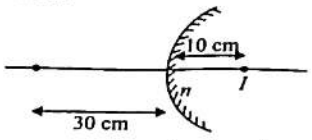


By lens formula, $\dfrac{1}{60} + \dfrac{1}{30} = \dfrac{1}{f_1}$

$$\Rightarrow \frac{1}{f_1} = \frac{1}{60} + \frac{2}{60} \Rightarrow f_1 = 20 \text{ cm}$$

@FIKE_CBSE_@RAJ_EDUNET

Case 2



By mirror formula $\frac{1}{10}-\frac{1}{30}=\frac{1}{f_2}$

$\frac{3}{30}-\frac{1}{30}=\frac{1}{f_2}=\frac{2}{30}f_2=15=\frac{R}{2}$

$\Rightarrow R=30;\ R=30$ cm;

$\frac{R}{n-1}=20\text{ cm}=\frac{30}{n-1}$

$\Rightarrow 2n-2=3\Rightarrow n=2.4$

Refractive index of lens is 2.5.

102. (*a, c*) As thickness of film is uniform, the effective power of the film is zero. Therefore, we can consider refraction at glass air interface. In case I: Refraction from air to glass

$-\frac{\mu_1}{u}+\frac{\mu_2}{v}=\frac{\mu_2-\mu_1}{R}$

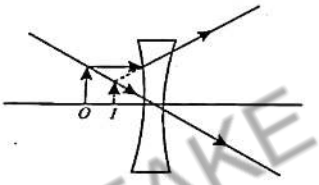
$-\frac{1}{\infty}+\frac{1.5}{f_1}=\frac{1.5-1}{R}$ or $f_1=3R$

In case II : Refraction from denser to rarer

$-\frac{\mu_2}{u}+\frac{\mu_1}{v}=\frac{\mu_1-\mu_2}{R}$

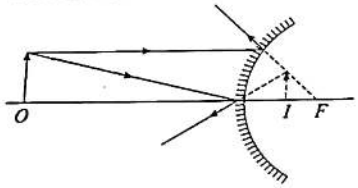
$-\frac{1.5}{\infty}+\frac{1}{f_2}=\frac{1-1.5}{R}$ or $f_2=2R$

103. (*b,c*) For a lens $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$, i.e. $\frac{1}{v}=\frac{1}{f}+\frac{1}{u}$



For a concave lens, f and u are negative, i.e. v will always be negative and image will always be virtual.

For a mirror :



$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ i.e. $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}$

Here, f is positive and u is negative for a convex mirror. Therefore, v is always positive and image is always virtual.

104. (*b,d*) When upper half of the lens is covered, image is formed by the rays coming from lower half of the lens. Or image will be formed by less number of rays. Therefore, intensity of image will decrease. But complete image will be formed.

105. (*a*)(I) $u=-20$ cm

$f=+10$ cm

$\frac{1}{v}+\frac{1}{20}=\frac{1}{10}\Rightarrow\frac{1}{v}=\frac{1}{10}-\frac{1}{20}$

$\frac{1}{v}=\frac{1}{20}$

$v=20$ cm

$u=+15$ cm

$f=+15$ cm

$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{v}-\frac{1}{15}=\frac{1}{15}$

$\frac{1}{v}=\frac{2}{15}$

$v=7.5$ cm (from lens 2)

I → P

(II) $u=-20$ cm, $f=+10$ cm

$\frac{1}{v}+\frac{1}{20}=\frac{1}{10}$

$\frac{1}{v}=\frac{1}{10}-\frac{1}{20}\Rightarrow v=20\,cm$

$u=+15$ cm

$f=-10$ cm

$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{v}-\frac{1}{15}=\frac{-1}{10}$

$\frac{1}{v}=\frac{-1}{10}+\frac{1}{15}=\frac{-3+2}{30}\Rightarrow\frac{1}{v}=-\frac{1}{30}$

$v=-30$ cm

II → R

(III) $u=-20$ cm

$f=+10$ cm

$\frac{1}{v}+\frac{1}{20}=\frac{1}{10}$

$\frac{1}{v}=\frac{1}{10}-\frac{1}{20}=\frac{1}{20}$

$v=20$ cm

$\Rightarrow u=15$ cm

$f=-20$ cm

$\frac{1}{v}-\frac{1}{15}=\frac{-1}{20}$

$\frac{1}{v}=-\frac{1}{20}+\frac{1}{15}=\frac{-3+4}{60}=\frac{1}{60}$

$v=60$ cm

III → Q

(IV) $u=-20$ cm

$f=-20$ cm

$\Rightarrow\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$\Rightarrow\frac{1}{v}+\frac{1}{20}=\frac{-1}{20}$

$v=-10$ cm

$u=-15$ cm

$f=10$ cm

$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$\frac{1}{v}+\frac{1}{15}=\frac{1}{10}$

$\Rightarrow\frac{1}{v}=\frac{1}{10}-\frac{1}{15}$

$=\frac{3-2}{30}=\frac{1}{30}$

$v=30$ cm

IV → T

106. (*b*) When both convex of radius of curvature r

$\frac{1}{f}=\left(\frac{3}{2}-1\right)\left(\frac{1}{r}+\frac{1}{r}\right)=\frac{1}{r}\Rightarrow f=r$

$\Rightarrow\frac{1}{f_{eq}}=\frac{1}{f}+\frac{1}{f}=\frac{2}{r}\Rightarrow f_{eq}=\frac{r}{2}$

When both planoconvex of radius of curvature r

$\frac{1}{f}=\left(\frac{3}{2}-1\right)\left(\frac{1}{r}\right)\Rightarrow f=2r$

$\frac{1}{\phi}+\frac{1}{\phi}=\frac{2}{\phi}=\frac{1}{p}\Rightarrow f_{eq}=-r$

When both planoconcave of radius of curvature r

$\frac{1}{f}=\left(\frac{3}{2}-1\right)\left(-\frac{1}{r}\right)=-\frac{1}{2r}\Rightarrow f=-2r$

$\frac{1}{f_{eq}}=\frac{1}{f}+\frac{1}{f}=-\frac{2}{2r}\Rightarrow f_{eq}=-r$

When one convex and one planoconcave of radius of curvature r

$\frac{1}{f_{eq}}=\frac{1}{r}+\frac{1}{-2r}=\frac{1}{2r}\Rightarrow f_{eq}=2r$

107. (A) → *p, r* (B) → q, s, t (C) → p, r, t (D) → q, s

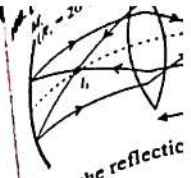
(*a*) (A) → since $\mu_1<\mu_2$, the ray of light will bend towards normal after first refraction.

(B) → $\mu_1>\mu_2$, the ray of light will bend away from the normal after first refraction.

(C) → since $\mu_2=\mu_3$ means in second refraction there will be no change in the path of ray of light.

(D) → Since $\mu_2>\mu_3$, ray of light will bend away from the normal after second refraction.

Therefore the correct options are as under.



For the reflectic

$\frac{1}{v}=\frac{1}{(-10)}+($

$\frac{1}{v}=\frac{1}{10}-\frac{1}{12}$

$v=+60$ cm

For refractio

$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$\frac{1}{v}-\frac{1}{-80}=$

$v=+\frac{80}{7}$

This imag

$\therefore\frac{20}{2}+\frac{8}{}$

$n=150$

If l_2 is f

Then,

$n=80$

And if

of M_1

$\frac{n}{7}=$

$\therefore n$

109. [1] C

$\Rightarrow$

Len

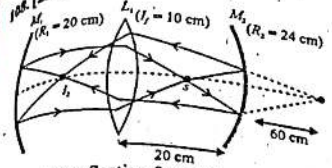
$\frac{1}{f}$

$\frac{1}{2}$

=

@FAKE_CBSE_X @RAJ_EDUNET

108. [220]



For the reflection from M_2,

$$\frac{1}{v}=\frac{1}{(-10)}+\frac{1}{(-12)}$$

$$\frac{1}{v}=\frac{1}{10}-\frac{1}{12}$$

$v = +60$ cm

For refraction from L_1,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{v}-\frac{1}{-80}=\frac{1}{10}$$

$$v=+\frac{80}{7} \text{ (for } I_2\text{)}$$

This image should be at focus of M_1

$$\therefore \frac{20}{2}+\frac{80}{7}=\frac{n}{7}$$

$n = 150$

If I_2 is formed at the pole of M_1,

Then, $\frac{n}{7}=\frac{80}{7}$

$n = 80$

And if I_2 is formed at the center of curvature of M_1.

$$\frac{n}{7}=\frac{80}{7}+20$$

$\therefore n = 220$

109. [1] Given, $u = 10 \pm 0.1$ cm,

$\Rightarrow v = 20 \pm 0.2$ cm

Lens Formula

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$$

$$\frac{1}{20}+\frac{1}{10}=\frac{1}{f}\Rightarrow\frac{1}{f}=\frac{3}{20}\Rightarrow f=\frac{20}{3}\text{ cm}$$

$$\Rightarrow\frac{1}{v^2}dv+\frac{1}{u^2}du=-\frac{1}{f^2}df$$

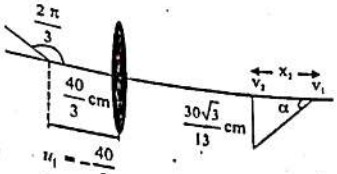
$$\Rightarrow\frac{1}{(20)^2}(0.2)+\frac{1}{(10)^2}(0.1)=\frac{9}{400}df$$

$$df=\frac{1}{9}\left(\frac{400}{400}\times0.2+\frac{400}{100}\times0.1\right)$$

$$df=\frac{0.6}{9}\Rightarrow\frac{df}{f}=\frac{0.6}{9}\times\frac{3}{20}=\frac{1}{100}$$

Error = 1%

110. [6]



$$u_1=-\frac{40}{3}$$

$f = 10$

$$\frac{1}{V_1}+\frac{1\times3}{40}=\frac{1}{10}$$

$V_1 = 40$

$$u_2=-\frac{43}{3}$$

$$\frac{1}{V_2}=\frac{1}{10}-\frac{3}{43}=\frac{43-30}{430}$$

$$V_2=\frac{430}{13}$$

$$x_2=V_1-V_{2=40}-\frac{430}{13}=\frac{90}{13}$$

$$\tan\alpha=\frac{30\sqrt{3}}{13\times x}=\frac{30\sqrt{3}\times13}{13\times90}=\frac{1}{\sqrt{3}}$$

$$\alpha=\frac{\pi}{6}=\frac{\pi}{n}$$

111. [1.39] For the given lens

$u = -30$ cm

$v = 60$ cm

& $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ on solving : $f = 20$ cm

also $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$

on differentiation

$$-\frac{df}{f^2}=-\frac{dv}{v^2}+\frac{du}{u^2}$$

$$\Rightarrow\left(\frac{df}{f^2}\right)_{max}=\frac{dv}{v^2}+\frac{du}{u^2}$$

$$\frac{df}{f}=f\left[\frac{dv}{v^2}+\frac{du}{u^2}\right]$$

and $\frac{df}{f}\times100=f\left[\frac{dv}{v^2}+\frac{du}{u^2}\right]\times100\%$

$f = 20$ cm,

$|u| = x_2 - x_1 = 30$ cm

Since there are 4 divisions in 1 cm on scale

$du = 0.25 + 0.25 = 0.50$

$|v| = x_3 - x_2 = 60$ cm

$dv = 0.25 + 0.25 = 0.50$ cm

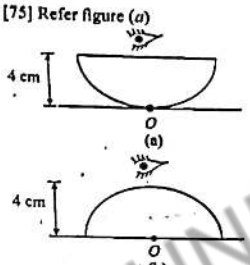
$$\therefore \frac{df}{f}\times100=20$$

$$\left[\frac{0.50}{(60)^2}+\frac{0.50}{(30)^2}\right]\times100\%$$

$$=10\left[\frac{1}{3600}+\frac{1}{900}\right]\times100\%$$

$$=10\left[\frac{5}{36}\right]\%\doteq\frac{50}{36}\%\approx1.39\%$$

112. [75] Refer figure (*a*)



(*b*) In this case refraction of the rays starting from *O* takes place from a plane surface. So, we can use

$$d_{app}=\frac{d_{actual}}{\mu}\text{ or }3=\frac{4}{\mu}\text{ or }\mu=\frac{4}{3}$$

Refer figure (*b*) In this case refraction takes place from a spherical surface. Hence, applying

$$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$$

we have, $\frac{1}{(-25/8)}-\frac{4/3}{-4}=\frac{1-4/3}{-R}$

or $\frac{1}{3R}=\frac{1}{3}-\frac{8}{25}=\frac{1}{75}$

$\therefore R = 25$ cm

Now, to find the focal length we will use the lens Maker's formula

$$\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$\therefore f = 75$ cm

113. [6.06] Applying Snell's law on face *AB*

(1) $\sin45^\circ=\left(\sqrt{2}\right)\sin r$

$\therefore \sin r=\frac{1}{2}$ or $r = 30^\circ$

i.e. ray becomes parallel to *AD* inside the block.

Now applying,

$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$ on face *CD*,

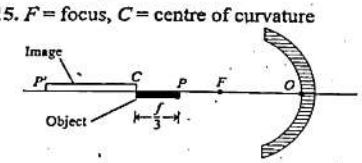
$$\frac{1.514}{OE}-\frac{\sqrt{2}}{\infty}=\frac{1.514-\sqrt{2}}{0.4}$$

Solving this equation, we get $OE = 6.06$ m

@FAKE_CBSE_K @RAJ_EDUNET

114. When the lenses are in contact, the power of the system is
$P = P_1 + P_2$ or $P_1 + P_2 = 10$
When lenses are separated by a distance
$d = 0.25 \text{ m} = \frac{1}{4} \text{ m}$
The power is $P = P_1 + P_2 - dP_1P_2$
or $P_1 + P_2 - \frac{P_1P_2}{4} = 6$
Solving Eqs. (*i*) and (*ii*), we can find that $P_1 = 8\text{D}$ and $P_2 = 2\text{D}$
$\therefore f_1 = \frac{1}{8} \text{ m} = 0.125 \text{ m}$
$\Rightarrow f_2 = \frac{1}{2} \text{ m} = 0.5 \text{ m}$

115. F = focus, C = centre of curvature

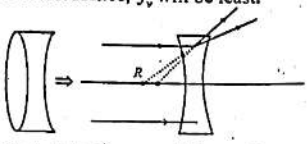


When the object lies between F and C, image is real, elongated and inverted. As one end of rod just touches its image, this end should lie at C. Because image of object at C is at C itself.
Let P be the image of other end of rod P.
For P
$u = -(2f - f/3) = -\frac{5f}{3}$
Applying the mirror formula : $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$
or $\frac{1}{v} - \frac{3}{5f} = \frac{1}{-f} \Rightarrow \frac{1}{v} = \frac{3}{5f} - \frac{1}{f}$
$v = -\frac{5f}{2}$ or $OP' = \frac{5f}{2}$
$\therefore$ Length of image of rod
$CP' = OP' - OC = \frac{5f}{2} - 2f = \frac{f}{2}$
$\therefore$ Magnification $= -\frac{f/2}{f/3} = -1.5$
Here, negative sign implies that image is inverted.

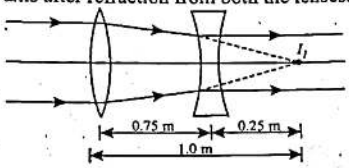
116. $\frac{1}{f_{air}} = (1.5 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ ...(*i*)
$\frac{1}{f_{medium}} = \left(\frac{1.5}{4/3} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ ...(*ii*)
Dividing Eq. (*i*) by Eq. (*ii*), we get
$\frac{f_{medium}}{f_{air}} = 4$
$\therefore f_{medium} = 4f_{air} = 4 \times 15 = 60 \text{ cm}$

117. $d = f_1 - f_2$
By using the formula
$\frac{1}{f_1} + \frac{1}{f_1} - \frac{d}{f_1f_2} = \frac{1}{F}$
For the emergent beam to parallel
$P = 0, F = \infty$
$\frac{1}{20} - \frac{1}{5} + \frac{d}{100} = 0$
$d = 15$

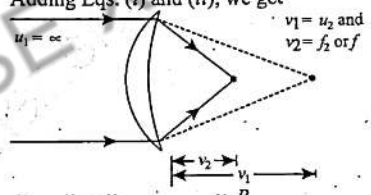
118. [True] Focal length of concave is less, i.e. power of concave lens will be more. Hence, the combination will behave like a concave lens. Further, μ_v is greater than all other colours. Hence, f_v will be least.



119. [False] At I_1, second focus of convex lens coincides with first focus of concave lens. Hence, rays will become parallel to the optic axis after refraction from both the lenses.

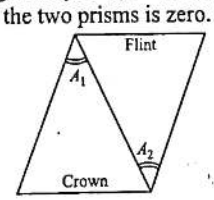


120. For refraction at first surface,
$\frac{\mu_2}{v_1} - \frac{\mu_1}{-\infty} = \frac{\mu_2 - \mu_1}{+R}$ ...(*i*)
For refraction at second surface,
$\frac{\mu_3}{v_2} - \frac{\mu_2}{v_1} = \frac{\mu_3 - \mu_2}{+R}$ ...(*ii*)
Adding Eqs. (*i*) and (*ii*), we get



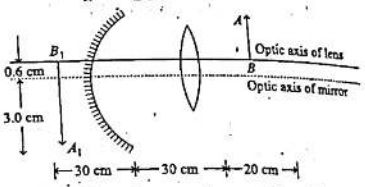
$\frac{\mu_3}{v_2} = \frac{\mu_3 - \mu_1}{R}$ or $v_2 = \frac{\mu_3 R}{\mu_3 - \mu_1}$
Therefore, focal length of the given lens system is $\frac{\mu_3 R}{\mu_3 - \mu_1}$

121. (*a*) When angle of prism is small and angle of incidence is also small, the deviation is given by $\delta = (\mu - 1)A$. Net deviation by the two prisms is zero. So,



or $(\mu - 1)A_1 + (\mu_2 - 1)A_2 = 0$
Here, μ_1 and μ_2 are the refractive indices for crown and flint glasses respectively.
Hence,
$\mu_1 = \frac{1.51 + 1.49}{2} = 1.5$ and
$\mu_2 = \frac{1.77 + 1.73}{2} = 1.75$
A_1 = Angle of prism for crown glass = 6°
Substituting the values in Eq. (*i*), we get
$(1.5 - 1)(6°) + (1.75 - 1)A_2 = 0$
This gives $A_2 = -4°$
Hence, angle of flint glass prism is 4°
(Negative sign shows that flint glass prism is inverted with respect to the crown glass prism.)
(*b*) Net dispersion due to the two prisms is
$= (\mu_b - \mu_r)A_1 + (\mu_b - \mu_r)A_2$
$= (1.51 - 1.49)(6°) + (1.77 - 1.73)(-4°)$
$= -0.04°$
$\therefore$ Net dispersion is $-0.04°$

122. (*a*) Rays coming from object AB first refract from the lens and then reflect from the mirror.
Refraction from the lens
$u = -20 \text{ cm}, f = +15 \text{ cm}$
Using lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$
$\Rightarrow \frac{1}{v} - \frac{1}{-20} = \frac{1}{15}$ $\therefore v = +60 \text{ cm}$
and linear magnification,
$m_1 = \frac{v}{u} = \frac{+60}{-20} = -3$



i.e. first image formed by the lens will be at 60 cm from it (or 30 cm from mirror) towards left and 3 times magnified but inverted. Length of first image A_1B_1 would be $1.2 \times 3 = 3.6$ cm (inverted).
Reflection from mirror Image formed by lens (A_1B_1) will behave like a virtual object for mirror at a distance of 30 cm from it as shown.
Therefore $u = +30 \text{ cm}, f = -30 \text{ cm}$.
Using mirror formula, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$
or $\frac{1}{v} + \frac{1}{30} = -\frac{1}{30}$
$\therefore v = -15 \text{ cm}$
and linear magnification,
$m_2 = -\frac{v}{u} = -\frac{-15}{+30} = +\frac{1}{2}$
i.e. final image $A'B'$ will be located at a distance of 15 cm from the mirror

@FAKE_CBSE_Y@RAJ_EDUNET

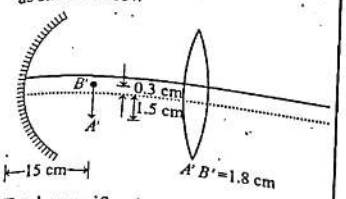
(towards right) and since magnification is $+\frac{1}{2}$, length of final image would be

$3.6\times\frac{1}{2}=1.8$ cm.

$\therefore A'B'=1.8$ cm

Point B_1 is 0.6 cm above the optic axis of mirror, therefore, its image B' would be $(0.6)\frac{1}{2}=0.3$ cm above optic axis.

Similarly, point A_1 is 3 cm below the optic axis, therefore, its image A' will be $3\times\frac{1}{2}=1.5$ cm below the optic axis as shown below



Total magnification of the image,

$m=m_1\times m_2=(-3)\left(+\frac{1}{2}\right)=-\frac{3}{2}$

$\therefore A'B'=(m)(AB)=\left(-\frac{3}{2}\right)(1.2)$

$=-1.8$ cm

Note that, there is no need of drawing the ray diagram if not asked in the question.

123. Applying $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$

First on plane surface

$\frac{1.5}{AI_1}-\frac{1}{-mR}=\frac{1.5-1}{\infty}=0$

$\therefore AI_1=-(1.5\text{ mR})$

Then, on curved surface

$\frac{1}{\infty}-\frac{1.5}{-(1.5mR+R)}=\frac{1-1.5}{-R}$

[$v=\infty$, because final image is at infinity]

$\Rightarrow\frac{1.5}{(1.5m+1)R}=\frac{0.5}{R}\Rightarrow 3=1.5\text{ m}+1$

$\Rightarrow\frac{3}{2}m=2$ or $m=\frac{3}{4}$

124. From lens maker's formula,

$\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

we have $\frac{1}{0.3}=\left(\frac{3}{2}-1\right)\left(\frac{1}{R}-\frac{1}{-R}\right)$

$R=0.3$

Now applying $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$ at air glass surface, we get

$\frac{3/2}{v_1}-\frac{1}{-(0.9)}=\frac{3/2-1}{0.3}$

$\therefore v_1=2.7$ m

i.e. first image I_1 will be formed at 2.7 m from the lens. This will act as the virtual object for glass water surface. Therefore, applying $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$ at glass water surface, we have

$\frac{4/3}{v_2}-\frac{3/2}{2.7}=\frac{4/3-3/2}{-0.3}$

$\therefore v_2=1.2$ m

i.e. second image I_2 is formed at 1.2 m from the lens or 0.4 m from the plane mirror. This will act as a virtual object for mirror. Therefore, third real image I_3 will be formed at a distance of 0.4 m in front of the mirror after reflection from it. Now this image will work as a real object for water-glass interface. Hence, applying

$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$

we get $\frac{3/2}{v_4}-\frac{4/3}{-(0.8-0.4)}=\frac{3/2-4/3}{0.3}$

$\therefore v_4=-0.54$ m

i.e. fourth image is formed to the right of the lens at a distance of 0.54 m from it. Now finally applying the same formula for glass-air surface,

$\frac{1}{v_3}-\frac{3/2}{-0.54}=\frac{1-3/2}{-0.3}$

$\therefore v_3=-0.9$ m

i.e. position of final image is 0.9 m relative to the lens (rightwards) or the image is formed 0.1 m behind the mirror.

125. From first figure it is clear that $\mu=\mu_1$

From second figure it is clear that $\mu=\mu_2$

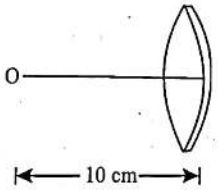
$\therefore \mu_1<\mu_2$

126. The given system behaves like a mirror of power given by

$P=2P_L+P_M$

or $-\frac{1}{F}=2\left(\frac{1}{0.2}\right)+\left(\frac{-2}{0.22}\right)$

As $P_L=\frac{1}{f(\text{m})}$ and $P_M=\frac{-1}{f(\text{m})}=\frac{-2}{R(\text{m})}$



Solving this equation, we get

$F=-1.1\text{ m}=-110$ cm

i.e. the system behaves as a concave mirror of focal length 18.33 cm.

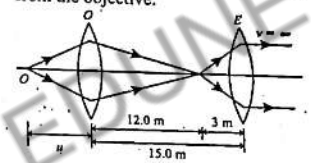
Using the mirror formula

$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ we have $\frac{1}{v}-\frac{1}{10}=-\frac{1}{110}$

or $=11$ cm

i.e. virtual image will be formed at a distance of 11 cm.

127. (*a*) Since, the final image is formed at infinity, the image formed by the objective will be at the focal point of the eyepiece, which is 3.0 cm. The image formed by the objective will be at a distance of 12.0 cm(=15 cm −3.0 cm) from the objective.



If u is the distance of the object from the objective, we have

$\Rightarrow\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\therefore\frac{1}{12}-\frac{1}{-u}=\frac{1}{2}$

$u=2.4$ cm

128. (*d*) $L_\infty=f_o+f_e=36$ ...(*i*)

Further angular magnification is given as 5. Therefore,

$M_\infty=\frac{f_o}{f_e}=5$ ...(*ii*)

Solving Eqs. (*i*) and (*ii*), we get

$f_o=30$ cm and $f_e=6$ cm

129. (*a,b,c,d*) Distance between objective and eyepiece

$L=f_o+f_e=(16+0.02)\text{ m}=16.02$

Angular magnification

$M=-f_o/f_e=-16/0.02=-800$

Image is inverted and objective is larger than the eyepiece.

[option (*c*)]

130. (A) → p; (B) → r; (C) → r; (D) → p,q,r; In case of concave mirror or convex lens image can be real, virtual, diminished magnified or of same size. In case of convex mirror image is always virtual (for real object).

131. The resolving power of a microscope is inversely proportional to the wavelength of the wave used. de-Broglie matter wave is used in case of an electron microscope whose wavelength is less than the wavelength of visible light used in optical microscope.

@FAKE_CBSE_@RAJ_EDUNET

26 Wave Optics

Scan for Sol.

JEE-Main

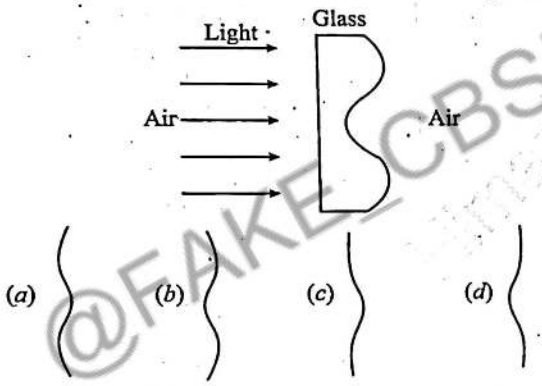
Huygen'S Wave Theory and Interference

1. Light emerges out of a convex lens when a source of light kept at its focus. The shape of wavefront of the light is:

[05 April, 2024 (Shift-I)]

(a) Both spherical and cylindrical
(b) Cylindrical
(c) Spherical
(d) Plane

2. A parallel beam of light strikes a piece of transparent glass having cross section as shown in the figure below. Correct shape of the emergent wave front will be (figures are schematic and not drawn to scale) **[JEE Adv, 2020]**



Normal YDSE and White Light

3. In Young's double slit experiment, monochromatic light of wavelength 5000 Å is used. The slits are 1.0 mm apart and screen is placed at 1.0 m away from slits. The distance from the centre of the screen where intensity becomes half of the maximum intensity for the first time is _____ $\times 10^{-6}$ m.

[1 Feb, 2024 (Shift-II)]

4. In Young's double slit experiment, light from two identical sources are superimposing on a screen. The path difference between the two lights reaching at a point on the screen is $\frac{7\lambda}{4}$. The ratio of intensity of fringe at this point with respect to the maximum intensity of the fringe is: **[29 Jan, 2024 (Shift-II)]**

(a) $\frac{1}{2}$ (b) $\frac{3}{4}$ (c) $\frac{1}{3}$ (d) $\frac{1}{4}$

5. In a Young's double slit experiment, the intensity at a point is $\left(\frac{1}{4}\right)^{th}$ of the maximum intensity, the minimum distance of the point from the central maximum is _____ μm.
(Given: $\lambda = 600$ nm, $d = 1.0$ mm, $D = 1.0$ m)

[09 April, 2024 (Shift-I)]

6. Two coherent monochromatic light beams of intensities I and $4I$ are superimposed. The difference between maximum and minimum possible intensities in the resulting beam is xI. The value of x is_____. **[06 April, 2024 (Shift-II)]**

7. In a single slit experiment, a parallel beam of green light of wavelength 550 nm passes through a slit of width 0.20 mm. The transmitted light is collected on a screen 100 cm away. The distance of first order minima from the central maximum will be $x \times 10^{-5}$ m. The value of x is: **[05 April, 2024 (Shift-II)]**

8. In Young's double slit experiment, carried out with light of wavelength 5000 Å, the distance between the slits is 0.3 mm and the screen is at 200 cm from the slits. The central maximum is at $x = 0$ cm. The value of x for third maxima is ..... mm.

[05 April, 2024 (Shift-I)]

9. Two wavelengths λ_1 and λ_2 are used in Young's double slit experiment $\lambda_1 = 450$ nm and $\lambda_2 = 650$ nm. The minimum order of fringe produced by λ_2 which overlaps with the fringe produced by λ_1 is n. The value of n is _____. **[04 April, 2024 (Shift-I)]**

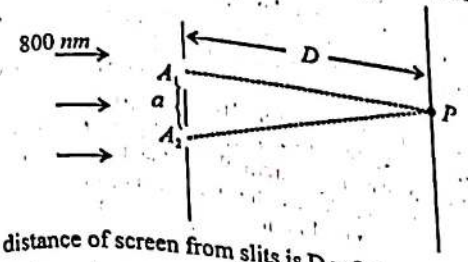
10. The width of one of the two slits in a Young's double slit experiment is 4 times that of the other slit. The ratio of the maximum to the minimum intensity in the interference pattern is:

[04 April, 2024 (Shift-II)]

(a) 9 : 1 (b) 16 : 1 (c) 1 : 1 (d) 4 : 1

@FAKE_CBSE_X_ORAL_EDUNEXT

11. In a Young's double slit experiment, two slits are illuminated with a light of wavelength 800 *nm*. The line joining A_1P is perpendicular to A_1A_2 as shown in the figure below. If the first minimum is detected at P, the value of slits separation 'a' will be: **[29 Jan, 2023 (Shift-I)]**



The distance of screen from slits is D = 5 *cm*

(*a*) 0.4 mm (*b*) 0.5 mm
(*c*) 0.2 mm (*d*) 0.1 mm

12. The ratio of intensities at two points P and Q on the screen in a Young's double slit experiment where phase difference between two wave of same amplitude are $\pi/3$ and $\pi/2$, respectively are **[10 April, 2023 (Shift-II)]**

(*a*) 1 : 3 (*b*) 3 : 1 (*c*) 3 : 2 (*d*) 2 : 3

13. In Young's double slits experiment, the position of 5th bright fringe from the central maximum is 5cm. The distance between slits and the screen is 1m and wavelength of monochromatic light used is 600nm. The separation between the slits is: **[25 Jan, 2023 (Shift-I)]**

(*a*) 60μm (*b*) 48μm (*c*) 12μm (*d*) 36μm

14. The width of fringe is 2 mm on the screen in a double slits experiment for the light of wavelength of 400 nm. The width of the fringe for the light of wavelength 600 nm will be: **[8 April, 2023 (Shift-II)]**

(*a*) 4 mm (*b*) 1.33 mm (*c*) 3 mm (*d*) 2 mm

15. In a Young's double slits experiment, the ratio of amplitude of light coming from slits is 2 : 1. The ratio of the maximum to minimum intensity in the interference pattern is: **[13 April, 2023 (Shift-II)]**

(*a*) 9 : 4 (*b*) 9 : 1 (*c*) 2 : 1 (*d*) 25 : 9

16. Two light waves of wavelengths 800 and 600 nm are used in Young's double slit experiment to obtain interference fringes on a screen placed 7 m away from plane of slits. If the two slits are separated by 0.35 mm, then shortest distance from the central bright maximum to the point where the bright fringes of the two wavelength coincide will be _____ mm. **[31 Jan, 2023 (Shift-II)]**

17. In a Young's double slit experiment, the intensities at two points, for the path difference $\frac{\lambda}{4}$ and $\frac{\lambda}{3}$ (λ being the wavelength of light used) are I_1 and I_2 respectively. If I_0 denotes the intensity produced by each one of the individual slits, then $\frac{I_1+I_2}{I_0}$ = _____. **[30 Jan, 2023 (Shift-II)]**

18. A beam of light consisting of two wavelengths 7000Å and 5500Å is used to obtain interference pattern in Young's double slit experiment. The distance between the slits is 2.5 mm and the distance between the plane of slits and the screen is 150 cm. The least distance from the central fringe, where the bright fringes due to both the wavelengths coincide, is $n \times 10^{-5}$. The value of n is _____. **[6 April, 2023 (Shift-II)]**

19. In young's double slit experiment performed using a monochromatic light of wavelength λ, when a glass plate ($\mu = 1.5$) of thickness $x\lambda$ is introduced in the path of the one of the interfering beams, the intensity at the position where the central maximum occurred previously remains unchanged. The value of x will be: **[28 June, 2022 (Shift-II)]**

(*a*) 3 (*b*) 2 (*c*) 1.5 (*d*) 0.5

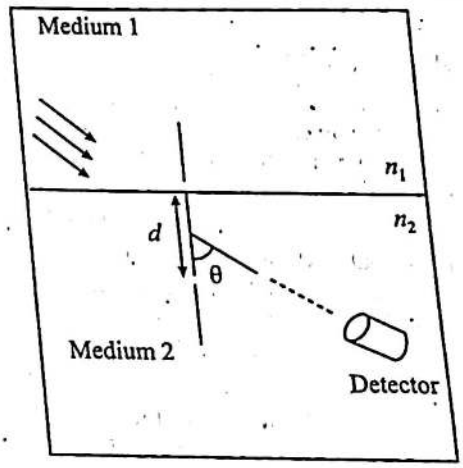
20. Using Young's double slit experiment, a monochromatic light of wavelength 5000 Å produces fringes of fringe width 0.5 mm. If another monochromatic light of wavelength 6000 Å is used and the separation between the slits is doubled, then the new fringe width will be **[29 June, 2022 (Shift-I)]**

(*a*) 0.5 mm (*b*) 1.0 mm (*c*) 0.6 mm (*d*) 0.3 mm

21. In Young's double slit experiment the two slits are 0.6 mm distance apart. Interference pattern is observed on a screen at a distance 80 cm from the slits. The first dark fringe is observed on the screen directly opposite to one of the slits. The wavelength of light will be _____ nm. **[27 June, 2022 (Shift-I)]**

22. In a double slit experiment with monochromatic light, fringes are obtained on a screen placed at some distance from the plane of slits. If the screen is moved by 5×10^{-2} m towards the slits, the change in fringe width is 3×10^{-3} cm. If the distance between the slits is 1 mm, then the wavelength of the light will be _____ nm. **[29 June, 2022 (Shift-II)]**

23. A double slit setup is shown in the figure. One of the slits is in medium 2 of refractive index n_2. The other slit is at the interface of this medium with another medium 1 of refractive index n_1 ($\neq n_2$). The line joining the slits is perpendicular to the interface and the distance between the slits is d. The slit widths are much smaller than d. A monochromatic parallel beam of light is incident on the slits from medium 1. A detector is placed in medium 2 at a large distance from the slits, and at an angle θ from the line joining them, so that θ equals the angle of refraction of the beam. Consider two approximately parallel rays from the slits received by the detector. **[JEE Adv, 2022]**



(*a*) The phase difference between the two rays is independent of d.

(*b*) The two rays interfere constructively at the detector.

(*c*) The phase difference between the two rays depends on n. but is independent to ny.

(*d*) The phase difference between the two rays vanishes only for certain values of d and the angle of incidence of the beam, with θ being the corresponding angle of refraction.

@FIRE OF X SIR EDUCATION

24. In Young's double slit arrangement, slits are separated by a gap of 0.5 mm and the screen is placed at a distance of 0.5 m from them. The distance between the first and the third bright fringe formed when the slits are illuminated by a monochromatic light of 5890 Å is **[18 March, 2021 (Shift-I)]**

(a) 1178×10^{-9} m (b) 1178×10^{-6} m

(c) 1178×10^{-12} m (d) 5890×10^{-7} m

25. In a Young's double slit experiment two slits are separated by 2 mm and the screen is placed one meter away. When a light of wavelength 500nm used, the fringe separation will be: **[26 Feb, 2021 (Shift-I)]**

(a) 1 mm (b) 0.75 mm (c) 0.25 mm (d) 0.50 mm

26. In the Young's double slit experiment, the distance between the slits varies in time as $d(t) = d_0 + a_0 \sin\omega t$; where d_0, ω and a_0 are constants. The difference between the largest fringe width and the smallest fringe width obtained over time is given as: **[25 July, 2021 (Shift-I)]**

(a) $\frac{\lambda D}{d_0 + a_0}$ (b) $\frac{\lambda D}{d_0^2} a_0$

(c) $\frac{2\lambda D a_0}{(d_0^2 - a_0^2)}$ (d) $\frac{2\lambda D(d_0)}{(d_0^2 - a_0^2)}$

27. If the source of light used in a Young's double slit experiment is changed from red to violet: **[24 Feb, 2021 (Shift-II)]**

(a) The fringes will become brighter.

(b) Consecutive fringe lines will come closer

(c) The central bright fringe will become a dark fringe

(d) The intensity of minima will increase

28. In a Young's double slit experiment, the width of the one of the slit is three times the other slit. The amplitude of the light coming from a slit is proportional to the slit-width. Find the ratio of the maximum to the minimum intensity in the interference pattern. **[24 Feb, 2021 (Shift-I)]**

(a) 1:4 (b) 4:1 (c) 3:1 (d) 2:1

29. The width of one of the two slits in a Young's double slit experiment is three times the other slit. If the amplitude of light coming from a slit is proportional to the slit-width, the ratio of minimum to maximum intensity in the interference pattern is $x : 4$ where x is _____. **[1 Sep, 2021 (Shift-II)]**

30. In a Young's double slit experiment, the slits are separated by 0.3 mm and the screen is 1.5 m away from the plane of slits. Distance between fourth bright fringes on both sides of central bright is 2.4 cm. The frequency of light used is _____ $\times 10^{14}$ Hz. **[31 Aug, 2021 (Shift-II)]**

31. A fringe width of 6 mm was produced for two slits separated by 1 mm apart. The screen is placed 10 m away. The wavelength of light used is 'x' nm. The value of 'x' to the nearest integer is _____. **[16 March, 2021 (Shift-I)]**

32. A beam of electrons of energy E scatters from a target having atomic spacing of 1 Å. The first maximum intensity occurs at $\theta = 60°$. Then E (in eV) is _____. (Planck constant $h = 6.64 \times 10^{-34}$ Js, 1 eV = 1.6×10^{-19} J, electron mass $m = 9.1 \times 10^{-31}$ kg). **[5 Sep, 2020 (Shift-I)]**

33. In a double-slit experiment, at a certain point on the screen the path difference between the two interfering waves is 1/8 of a wavelength. The ratio of the intensity of light at that point to that at the centre of a bright fringe is: **[8 Jan, 2020 (Shift-II)]**

(a) 0.672 (b) 0.568 (c) 0.760 (d) 0.853

34. Interference fringes are observed on a screen by illuminating two thin slits 1mm apart with a light source ($\lambda = 632.8$ nm). The distance between the screen and the slits is 100 cm. If a bright fringe is observed on a screen at a distance of 1.27 mm from the central bright fringe, then the path difference between the waves, which are reaching this point from the slits is close is **[2 Sep, 2020 (Shift-I)]**

(a) 1.27 μm (b) 2.05 μm (c) 2.87 μm (d) 2 μm

35. In a Young's double slit experiment, light of 500 nm is used to produce an interference pattern. When the distance between the slits is 0.05 mm, the angular width (in degree) of the fringes formed on the distance screen is close to: **[3 Sep, 2020 (Shift-I)]**

(a) 0.17° (b) 1.7° (c) 0.57° (d) 0.07°

36. In a Young double slit experiment, the separation between the slits is 0.15 mm. In the experiment, a source of light of wavelength 589 nm is used and the interference pattern is observed on screen kept 1.5 m away. The separation between the successive bright fringes on the screen is **[7 Jan, 2020 (Shift-II)]**

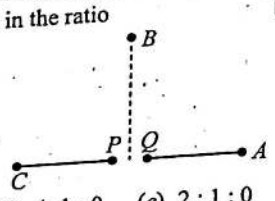
(a) 4.9 mm (b) 3.9 mm (c) 5.9 mm (d) 6.9 mm

37. In a Young's double slit experiment, 16 fringes are observed in a certain segment of the screen when light of a wavelength 700 nm is used. If the wavelength of light is changed to 400 nm, the number of fringes observed in the same segment of the screen would be **[2 Sep, 2020 (Shift-II)]**

(a) 28 (b) 24 (c) 30 (d) 18

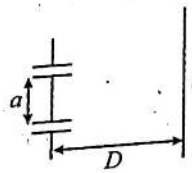
38. In a Young's double's slit experiment 15 fringes are observed on a small portion of the screen when light of wavelength 500 nm is used. Ten fringes are observed on the same section of the screen when another light source of wavelength λ is used. Then the value of λ is (in nm) _____. **[9 Jan, 2020 (Shift-II)]**

39. In the figure below, P and Q are two equally intense coherent sources emitting radiation of wavelength 20 m. The separation between P and Q is 5 m and the phase of P is ahead of that of Q by 90°. A, B and C are three distinct points of observation, each equidistant from the midpoint of PQ. The intensities of radiation at A, B, C will be in the ratio **[6 Sep, 2020 (Shift-I)]**



(a) 0 : 1 : 2 (b) 4 : 1 : 0 (c) 2 : 1 : 0 (d) 0 : 1 : 4

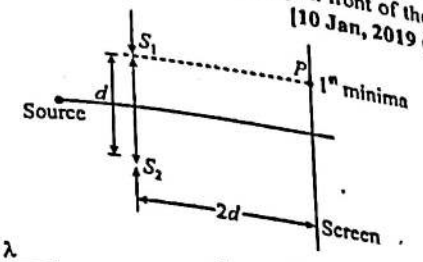
40. The figure shows a Young's double slit experimental setup. It is observed that when a thin transparent sheet of thickness t and refractive index μ is put in front of one of the slits, the central maximum gets shifted by a distance equal to n fringe widths. If the wavelength of light used is λ, t will be **[9 April, 2019 (Shift-I)]**



(a) $\frac{2nD\lambda}{a(\mu-1)}$ (b) $\frac{nD\lambda}{a(\mu-1)}$ (c) $\frac{2D\lambda}{a(\mu-1)}$ (d) $\frac{D\lambda}{a(\mu-1)}$

@NEET CEDEX @RL EDUNET

41. Consider a Young's double slit experiment as shown in figure. What should be the slit separation d in terms of wavelength λ such that the first minima occurs directly in front of the slit (S_1)? **[10 Jan, 2019 (Shift-II)]**



(a) $\frac{\lambda}{2(\sqrt{5}-2)}$ (b) $\frac{\lambda}{(\sqrt{5}-2)}$

(c) $\frac{\lambda}{2(5-\sqrt{2})}$ (d) $\frac{\lambda}{(5-\sqrt{2})}$

42. In a Young's double slit experiment, the path difference, at a certain point on the screen, between two interfering waves is 1/8th of wavelength. The ratio of the intensity at this point to that at the centre of a bright fringe is close to **[11 Jan, 2019 (Shift-I)]**

(a) 0.74 (b) 0.85 (c) 0.94 (d) 0.80

43. In a Young's double slit experiment, the slits are placed 0.320 mm apart. Light of wavelength $\lambda = 500$ nm is incident on the slits. The total number of bright fringes that are observed in the angular range $-30° \le \theta \le 30°$ is: **[9 Jan, 2019 (Shift-II)]**

(a) 640 (b) 320 (c) 321 (d) 641

44. In a double slit experiment, when a thin film of thickness t having refractive index μ is introduced in front of one of the slits, the maximum at the centre of the fringe pattern shifts by one fringe width. The value of t is (λ is the wavelength of the light used) **[12 April, 2019 (Shift-I)]**

(a) $\frac{\lambda}{2(\mu-1)}$ (b) $\frac{\lambda}{(2\mu-1)}$

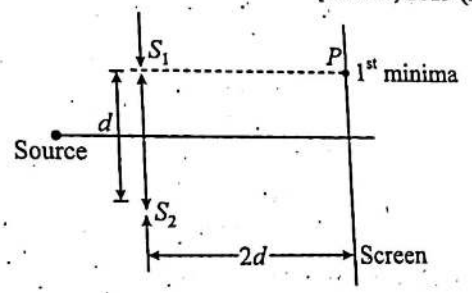
(c) $\frac{2\lambda}{(\mu-1)}$ (d) $\frac{\lambda}{(\mu-1)}$

45. In a Young's double slit experiment, the ratio of the slit's width is 4 : 1. The ratio of the intensity of maxima to minima, close to the central fringe on the screen, will be **[10 April, 2019 (Shift-II)]**

(a) $(\sqrt{3}+1)^4 : 16$ (b) 9 : 1

(c) 4 : 1 (d) 25 : 9

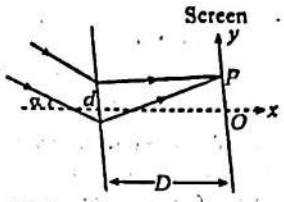
46. Consider a Young's double slit experiment as shown in figure. What should be the slit separation d in terms of wavelength λ such that the first minima occurs directly in front of the slit (S_1)? **[10 Jan, 2019 (Shift-II)]**



(a) $\frac{\lambda}{2(\sqrt{5}-2)}$ (b) $\frac{\lambda}{(\sqrt{5}-2)}$

(c) $\frac{\lambda}{2(5-\sqrt{2})}$ (d) $\frac{\lambda}{(5-\sqrt{2})}$

47. In a Young's double slit experiment, the slit separation d is 0.3 mm and the screen distance D is 1m. A parallel beam of light of wavelength 600nm is incident on the slits at angle α as shown in figure. On the screen, the point O is equidistant from the slits and distance PO is 11.0 m. Which of th following statements) is/ are correct? **[JEE Adv, 2019]**



(a) For $\alpha = \frac{0.36}{\pi}$ degree, there will be destructive interference at point O.

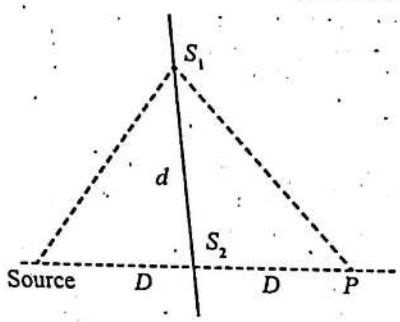
(b) Fringe spacing depends on α.

(c) For $\alpha = \frac{0.36}{\pi}$ degree, there will be destructive interference at point P.

(d) For $\alpha = 0$, there will be constructive interference at point P.

Modified YDSE Problems & Optical Path

48. In a double slit experiment shown in figure, when light of wavelength 400 nm is used, dark fringe is observed at P. If $D = 0.2$ m. the minimum distance between the slits S_1 and S_2 is _____ mm. **[29 Jan, 2024 (Shift-I)]**



[29 Jan, 2024 (Shift-I)]

49. Monochromatic light of wavelength 500 nm is used in Young's double slit experiment. An interference pattern is obtained on a screen When one of the slits is covered with a very thin glass plate (refractive index = 1.5), the central maximum is shifted to a position previously occupied by the 4th bright fringe. The thickness of the glass-plate is ..... μm. **[09 April, 2024 (Shift-II)]**

@TAKE_CBSE_K @RAJ_EDUNET

50. Given below are two statements: One is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**.

Assertion (A): The phase difference of two light waves change if they travel through different media having same thickness, but different indices of refraction.

Reason (R): The wavelengths of waves are different in different media.

In the light of the above statements, choose the most appropriate answer from the options given below **[6 April, 2023 (Shift-II)]**

(a) Both A and R are correct but R is not the correct explanation of A

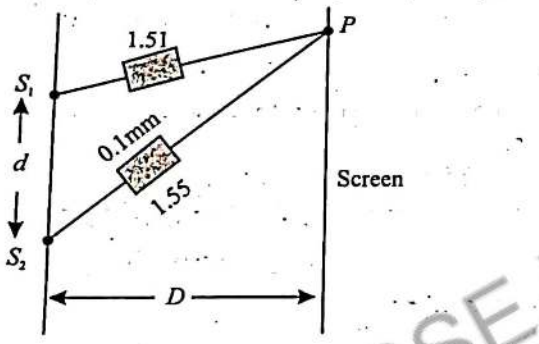
(b) A is correct but R is not correct

(c) Both A and R are correct and R is the correct explanation of A

(d) A is not correct but R is correct

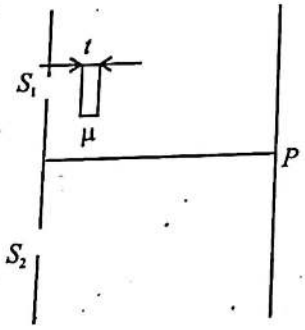
51. In Young's double slit experiment, two slits S_1 and S_2 are 'd' distance apart and the separation from slits to screen is D (as shown in figure). Now if two transparent slabs of equal thickness 0.1 mm but refractive index 1.51 and 1.55 are introduced in the path of beam ($\lambda = 4000\text{Å}$) from S_1 and S_2 respectively. The central bright fringe spot will shift by _____ number of fringes.

[30 Jan, 2023 (Shift-I)]



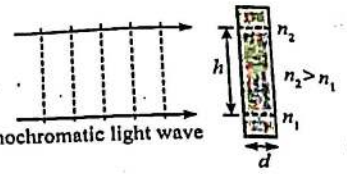
52. As shown in the figure, in Young's double slit experiment, a thin plate of thickness $t = 10\ \mu m$ and refractive index $\mu = 1.2$ is inserted infront of slit S_1. The experiment is conducted in air ($\mu = 1$) and uses a monochromatic light of wavelength $\lambda = 500\ nm$. Due to the insertion of the plate, central maxima is shifted by a distance of $X\beta_0$. β_0 is the fringe-width before the insertion of the plate. The value of the x is _____.

[1 Feb, 2023 (Shift-II)]



53. A monochromatic light wave is incident normally on a glass slab of thickness d, as shown in the figure. The refractive index of the slab increases linearly from n_1 to n_2 over the height h. Which of the following statement (s) is (are) true about the light wave emerging out of the slab?

[JEE Adv, 2023]



(a) It will deflect up by an angle $\tan^{-1}\left[\frac{(n_2^2 - n_1^2)d}{2h}\right]$

(b) It will deflect up by an angle $\tan^{-1}\left[\frac{(n_2 - n_1)d}{h}\right]$

(c) It will not deflect.

(d) The deflection angle depends only on $(n_2 - n_1)$ and not on the individual values of n_1 and n_2.

54. In Young's double slit experiment, the fringe width is 12 mm. If the entire arrangement is placed in water of refractive index $\frac{4}{3}$, then the fringe width becomes (in mm): **[26 July, 2022 (Shift-I)]**

(a) 16 (b) 9

(c) 48 (d) 12

55. In Young's double slit experiment, if the source of light changes from orange to blue then: **[27 July, 2021 (Shift-I)]**

(a) The distance between consecutive fringes will decrease.

(b) The distance between consecutive fringes will increase.

(c) The central bright fringe will become a dark fringe.

(d) The intensity of the minima will increase.

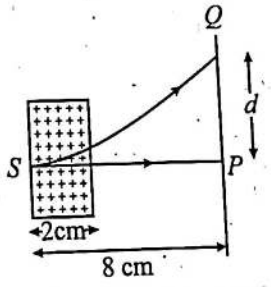
56. White light is passed through a double slit and interference is observed on a screen 1.5 m away. The separation between the slits is 0.3 mm. The first violet and red fringes are formed 2.0 mm and 3.5 mm away from the central white fringes. The difference in wavelengths of red and voilet light is _____ nm.

[26 Aug, 2021 (Shift-I)]

57. A Young's double-slit experiment is performed using monochromatic light of wavelength λ. The intensity of light at a point on the screen, where the path difference is λ, is K units. The intensity of light at a point where the path difference is $\frac{\lambda}{6}$ is given by $\frac{nK}{12}$, where n is an integer. The value of n is _____.

[6 Sep, 2020 (Shift-II)]

58. An electron, moving along the x-axis with an initial energy of 100 eV enters a region of magnetic field $\vec{B} = (1.5 \times 10^{-3} T)\hat{k}$ at S (See figure). The field extends between $x = 0$ and $x = 2$ cm. The electron is detected at the point Q on a screen placed 8 cm away from the point S. The distance d between P and Q (on the screen) is (Electron's charge = 1.6×10^{-19} C, mass of electron = 9.1×10^{-31} kg) **[12 April, 2019 (Shift-II)]**



(a) 12.87 cm (b) 1.22 cm (c) 11.65 cm (d) 2.25 cm

@PACE-CBSE X @PACE EDUNET

59. In a double - slit experiment, green light (5303 Å) falls on a double slit having a separation of 19.44 μm and a width of 4.05 μm. The number of bright fringes between the first and the second diffraction minima is
(a) 10 (b) 05 (c) 04 (d) 09
[11 Jan, 2019 (Shift-II)]

Diffraction of Light, Polarisation of Light, Malus Law

60. A microwave of wavelength 2.0 cm falls normally on a slit of width 4.0 cm. The angular spread of the central maxima of the diffraction pattern obtained on a screen 1.5 m away from the slit, will be:
(a) 30° (b) 15° (c) 60° (d) 45°
[1 Feb, 2024 (Shift-II)]

61. A monochromatic light of wavelength 6000Å is incident on the single slit of width 0.01 mm. If the diffraction pattern is formed at the focus of the convex lens of focal length 20 cm, the linear width of the central maximum is:
(a) 60 mm (b) 24 mm (c) 120 mm (d) 12 mm
[1 Feb, 2024 (Shift-I)]

62. The diffraction pattern of a light of wavelength 400 nm diffracting from a slit of width 0.2 mm is focused on the focal plane of a convex lens of focal length 100 cm. The width of the 1st secondary maxima will be:
(a) 2 mm (b) 2 cm
(c) 0.02 mm (d) 0.2 mm
[30 Jan, 2024 (Shift-I)]

63. A beam of unpolarised light of intensity I_0 is passed through a polaroid A and then through another polaroid B which is oriented so that its principal plane makes an angle of 45° relative to that of A. The intensity of emergent light is:
(a) $I_0/4$ (b) I_0
(c) $I_0/2$ (d) $I_0/8$
[30 Jan, 2024 (Shift-II)]

64. When unpolarized light is incident at an angle of 60° on a transparent medium from air. The reflected ray is completely polarized. The angle of refraction in the medium is
(a) 30° (b) 60° (c) 90° (d) 45°
[31 Jan, 2024 (Shift-II)]

65. In a single slit diffraction pattern, a light of wavelength 6000 Å is used. The distance between the first and third minima in the diffraction pattern is found to be 3 mm when the screen in placed 50 cm away from slits. The width of the slit is _____ $\times 10^{-4}$ m.
[29 Jan, 2024 (Shift-II)]

66. When a polaroid sheet is rotated between two crossed polaroids then the transmitted light intensity will be maximum for a rotation of :
(a) 60° (b) 30° (c) 90° (d) 45°
[27 JAN, 2024 (Shift-II)]

67. A parallel beam of monochromatic light of wavelength 5000Å is incident normally on a single narrow slit of width 0.001 mm. The light is focused by convex lens on screen, placed on its focal plane. The first minima will be formed for the angle of diffraction of _____(degree).
[27 JAN, 2024 (Shift-II)]

68. Two slits are 1 mm apart and the screen is located 1 m away from the slits. A light wavelength 500 nm is used. The width of each slit to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern is ..... $\times 10^{-4}$ m.
[08 April, 2024 (Shift-II)]

69. A parallel beam of monochromatic light of wavelength 600 nm passes through single slit of 0.4 mm width. Angular divergence corresponding to second order minima would be _____ $\times 10^{-3}$ rad.
[08 April, 2024 (Shift-I)]

70. Which of the following phenomena does not explain by wave nature of light.
(A) reflection (B) diffraction
(C), photoelectric effect (D) Interference
(E) polarization
Choose the most appropriate answer from the options given below:
[06 April, 2024 (Shift-I)]
(a) E only (b) C only
(c) B, D only (d) A, C only

71. 'n' polarizing sheets are arranged such that each makes an angle 45° with the preceeding sheet. An unpolarized light of intensity I is incident into this arrangement. The output intensity is found to be $\frac{I}{64}$. The value of n will be:
(a) 3 (b) 6 (c) 5 (d) 4
[1 Feb, 2023 (Shift-I)]

72. Given below are two statements:
Statement-I: If the Brewster's angle for the light propagating from air to glass is θ_B, then Brewster's angle for the light propagating from glass to air is $\frac{\pi}{2}-\theta_B$.
Statement-II: The Brewster's angle for the light propagating from glass to air is $\tan^{-1}(\mu_g)$ where μ_g is the refractive index of glass.
In the light of the above statements, choose the correct answer from the options given below :
(a) Both Statements-I and Statement-II are true.
(b) Statement-I is true but Statement-II is false.
(c) Both Statement-I and Statement-II are false
(d) Statement-I is false but Statement-II is true.
[24 Jan, 2023 (Shift-I)]

73. Two polaroids A and B are placed in such a way that the pass-axis of polaroids are perpendicular to each other. Now, another polaroid C is placed between A and B bisecting the angle between them. If intensity of unpolarised light is I_0 then intensity of transmitted light after passing through polaroid B will be:
(a) $\frac{I_0}{4}$ (b) $\frac{I_0}{2}$ (c) $\frac{I_0}{8}$ (d) Zero
[31 Jan, 2023 (Shift-I)]

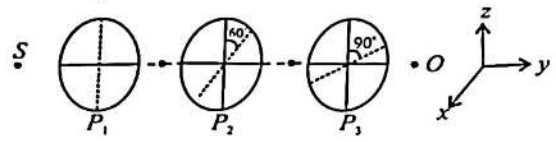
74. Unpolarised light of intensity 32 Wm^{-2} passes through the combination of three polaroids such that the pass axis of the last polaroid is perpendicular to that of the pass axis of first polaroid. If intensity of emerging light is 3 Wm^{-2}, then the angle between pass axis of first two polaroids is _____
[10 Apr 2023 Shift 1]

@TAKE CBSE X @RAJ_EDUNET

75. An unpolarised light is incident on the boundary between two dielectric media, whose dielectric constants are 2.8 (medium -1) and 6.8 (medium 2), respectively. To satisfy the condition, so that the reflected and refracted rays are perpendicular to each other, the angle of incidence should be $\tan^{-1}\left(1+\frac{10}{0}\right)^{\frac{1}{2}}$ the value of 0 is _____.

(Given for dielectric media, $\mu_r = 1$) **[29 Jan, 2023 (Shift-II)]**

76. As shown in the figures, three identical polaroids P_1, P_2 and P_3 are placed one after another. The pass axis of P_2 and P_3 are inclined at angle of 60° and 90° with respect to the axis of P_1. The source S has an intensity of $256\frac{W'}{m^2}$. The intensity of light at point O is _____ $\frac{W'}{m^2}$. **[29 Jan, 2023 (Shift-I)]**



77. An unpolarised light beam of intensity $2I_0$ is passed through a polaroid P and then through another polaroid Q which is oriented in such a way that its passing axis makes an angle of 30° relative to that of P. The intensity of the emergent light is

[29 July, 2022 (Shift-II)]

(a) $\frac{I_0}{4}$ (b) $\frac{I_0}{2}$ (c) $\frac{3I_0}{4}$ (d) $\frac{3I_0}{2}$

78. Sodium light of wavelength 650 nm and 655 nm is used to study diffraction at a single slit of aperture 0.5 mm. The distance between the slit and the screen is 2.0 m. The separation between the positions of the first maxima of diffraction pattern obtained in the two cases is _____ $\times 10^{-5}$ m. **[24 June, 2022 (Shift-I)]**

79. The speed of electrons in a scanning electron microscope is 1×10^7 ms^{-1}. If the protons having the same speed are used instead of electrons, then the resolving power of scanning proton microscope will be changed by a factor of

[18 March, 2021 (Shift-II)]

(a) 1837 (b) $\sqrt{1837}$ (c) $\frac{1}{\sqrt{1837}}$ (d) $\frac{1}{1837}$

80. Consider the diffraction pattern obtained from the sunlight incident on a pinhole of diameter 0.1μm. If the diameter of the pinhole is slightly increased, it will affect the diffraction pattern such that:

[25 Feb, 2021 (Shift-II)]

(a) Its size increases, but intensity decreases
(b) Its size increases, and intensity increases
(c) Its size decreases, but intensity increases
(d) Its size decreases, and intensity decreases

81. A source of light is placed in front of a screen. Intensity of light on the screen is I. Two Polaroids P_1 and P_2 are so placed in between the source of light and screen that the intensity of light on screen is $\frac{I}{2}$. P_2 should be rotated by an angle of _____ (degrees) so that the intensity of light on the screen becomes $\frac{3I}{8}$.

[26 Aug, 2021 (Shift-II)]

82. An unpolarized light beam is incident on the polarizer of a polarization experiment and the intensity of light beam emerging from the analyzer is measured as 100 Lumens. Now, if the analyzer is rotated around the horizontal axis (direction of light) by 30° in clockwise direction, the intensity of emerging light will be _____ Lumens. **[24 Feb, 2021 (Shift-I)]**

83. A polarizer analyser set is adjusted such that the intensity of light coming out of the analyser is just 10% of the original intensity. Assuming that the polarizer - analyser set does not absorb any light, the angle by which the analyser need to be rotated further to reduce the output intensity to be zero is **[7 Jan, 2020 (Shift-I)]**

(a) 45° (b) 90° (c) 71.6° (d) 18.4°

84. Visible light of wavelength 6000×10^{-8} cm falls normally on single slit and produces a diffraction pattern. It is found that the second diffraction minimum is at 60° from the central maximum. If the first minimum is produced at θ_1, then θ_1 is close to

[7 Jan, 2020 (Shift-I)]

(a) 25° (b) 30° (c) 20° (d) 45°

85. Orange light of wavelength 6000×10^{-10} m illuminates a single slit of width 0.6×10^{-4} m. The maximum possible number of diffraction minima produced on both sides of the central maximum is ____.

[4 Sep, 2020 (Shift-II)]

86. A beam of plane polarised light of large cross-sectional area and uniform intensity of 3.3 Wm^{-2} falls normally on a polariser (cross sectional area 3×10^{-4} m^2) which rotates about its axis with an angular speed of 31.4 rad/s. The energy of light passing through the polariser per revolution, is close to **[4 Sep, 2020 (Shift-I)]**

(a) 1.0×10^{-5} J (b) 1.0×10^{-4} J
(c) 5.0×10^{-4} J (d) 1.5×10^{-4} J

87. A system of three polarizers P_1, P_2, P_3, is set up such that the pass axis of P_3 is crossed with respect to that of P_1. The pass axis of P_2 is inclined at 60° to the pass axis of P_3. When a beam of unpolarized light of intensity I_0 is incident on P_1, the intensity of light transmitted by the three polarizers is I. The ratio (I_0/I) equals (nearly)

[12 April, 2019 (Shift-II)]

(a) 16.00 (b) 1.80 (c) 5.33 (d) 10.67

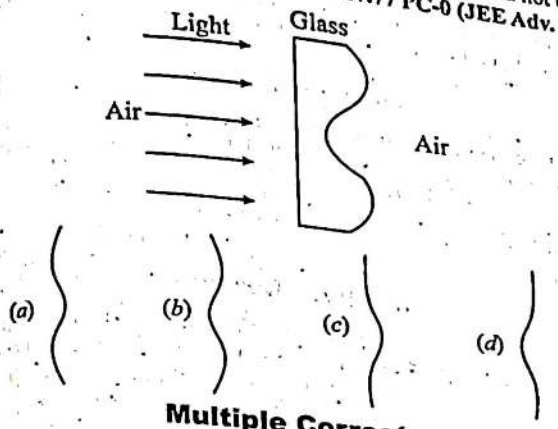
@PHYSICS_CHEMISTRY_@MATHEDUNET

JEE-Advanced

Huygen's Wave Theory and Interference

Single Correct

1. A parallel beam of light strikes a piece of transparent glass having cross section as shown in the figure below. Correct shape of the emergent wave front will be (figures are schematic and not drawn to scale) C-35.72 W-46.5 UA-17.77 PC-0 (JEE Adv. 2020)



Multiple Correct

2. White light is used to illuminate the two slits in a Young's double slit experiment. The separation between the slits is b and the screen is at a distance d ($>> b$) from the slits. At a point on the screen directly in front of one of the slits, certain wavelengths are missing. Some of these missing wavelengths are (IIT-JEE 1984)

(a) $\lambda = b^2/d$ (b) $\lambda = 2b^2/d$ (c) $\lambda = b^2/3d$ (d) $\lambda = 2b^2/3d$

3. In the Young's double slit experiment, the interference pattern is found to have an intensity ratio between the bright and dark fringes as 9. This implies that (IIT-JEE 1982)

(a) the intensities at the screen due to the two slits are 5 units and 4 units respectively

(b) the intensities at the screen due to the two slits are 4 units and 1 unit respectively

(c) the amplitude ratio is 3

(d) the amplitude ratio is 2

Fill in the Blanks

4. In Young's double-slit experiment, the two slits act as coherent sources of equal amplitude A and of wavelength λ. In another experiment with the same set-up the two slits are sources of equal amplitude A and wavelength λ, but are incoherent. The ratio of the intensity of light at the mid-point of the screen in the first case to that in the second case is..... (IIT-JEE 1986)

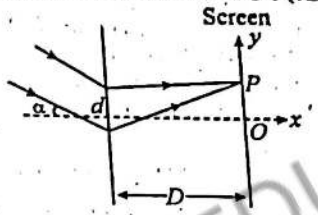
True/False

5. The intensity of light at a distance r from the axis of a long cylindrical source is inversely proportional to r. (IIT-JEE 1981)

Normal Ydse and White Light

Single Correct

6. In a Young's double slit experiment, the slit separation d is 0.3 mm and the screen distance D is 1m. A parallel beam of light of wavelength 600nm is incident on the slits at angle α as shown in figure. On the screen, the point O is equidistant from the slits and distance PO is 11.0 m. Which of th following statements) is/ are correct? C-8.7 W-53.35 UA-37.95 PC-0 (JEE Adv. 2019)



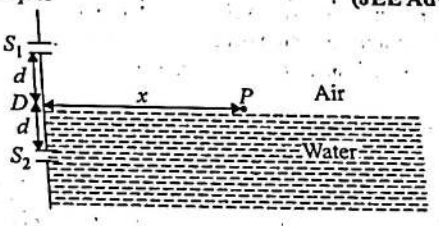
(a) For $\alpha = \frac{0.36}{\pi}$ degree, there will be destructive interference at point O.

(b) Fringe spacing depends on α..

(c) For $\alpha = \frac{0.36}{\pi}$ degree, there will be destructive interference at point P.

(d) For $\alpha = 0$, there will be constructive interference at point P.

7. A Young's double slit interference arrangement with slits S_1 and S_2 is immersed in water (refractive index = 4/3) as shown in the figure. The positions of maxima on the surface of water are given by $x^2 = p^2m^2\lambda^2 - d^2$, where λ is the wavelength of light in air (refractive index = 1), $2d$ is the separation between the slits and m is an integer. The value of p is (JEE Adv. 2015)



(a) $p = 1$ (b) $p = 2$ (c) $p = 3$ (d) $p = 4$

8. In the Young's double slit experiment using a monochromatic light of wavelength λ the path difference (in terms of an integer n) corresponding to any point having half the peak intensity is C-54.94 W-41.88 UA-3.18 (JEE Adv. 2013)

(a) $\frac{(2n+1)\lambda}{2}$ (b) $\frac{(2n+1)\lambda}{4}$

(c) $\frac{(2n+1)\lambda}{8}$ (d) $\frac{(2n+1)\lambda}{16}$

@TAKE_CBSE_X @RAJ_EDUNET

9. Using the expression $2d\sin\theta = \lambda$, one calculates the values of d by measuring the corresponding angles θ in the range 0 to 90°. The wavelength λ is exactly known and the error in θ is constant for all values of θ. As θ increases from 0°.

C-4.65 W-47.31 UA-48.05 (JEE Adv. 2013)

(a) The absolute error in d remains constant

(b) The absolute error in d increases

(c) The fractional error in d remains constant

(d) The fractional error in d decreases

10. In Young's double slit experiment intensity at a point is (1/4) of the maximum intensity. Angular position of this point is

(IIT-JEE 2005)

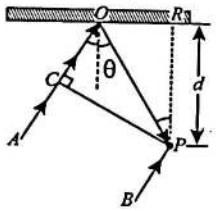
(a) $\text{Sin}^{-1}\left(\frac{\lambda}{d}\right)$ (b) $\text{Sin}^{-1}\left(\frac{\lambda}{2d}\right)$ (c) $\text{Sin}^{-1}\left(\frac{\lambda}{3d}\right)$ (d) $\text{Sin}^{-1}\left(\frac{\lambda}{4d}\right)$

11. In a YDSE bi-chromatic light of wavelengths 400 nm and 560 nm are used. The distance between the slits is 0.1 mm and the distance between the plane of the slits and the screen is 1 m. The minimum distance between two successive regions of complete darkness is

(IIT-JEE 2004)

(a) 4 mm (b) 5.6 mm (c) 14 mm (d) 28 mm

12. In the adjacent diagram, CP represents a wavefront and AO and BP, the corresponding two rays. Find the condition of θ for constructive interference at P between the ray BP and reflected ray OP (2003)



(a) $\cos\theta = \frac{3\lambda}{2d}$ (b) $\cos\theta = \frac{\lambda}{4d}$

(c) $\sec\theta - \cos\theta = \frac{\lambda}{d}$ (d) $\sec\theta - \cos\theta = \frac{4\lambda}{d}$

13. In the ideal double-slit experiment, when a glass-plate (refractive index 1.5) of thickness t is introduced in the path of one of the interfering beams (wavelength λ), the intensity at the position where the central maximum occurred previously remains unchanged. The minimum thickness of the glass-plate is (IIT-JEE 2002)

(a) 2λ (b) $\frac{2\lambda}{3}$ (c) $\frac{\lambda}{3}$ (d) λ

14. In a Young's double slit experiment, 12 fringes are observed to be formed in a certain segment of the screen when light of wavelength 600 nm is used. If the wavelength of light is changed to 400 nm, number of fringes observed in the same segment of the screen is given by (IIT-JEE 2001)

(a) 12 (b) 18 (c) 24 (d) 30

15. Two beams of light having intensities I and $4I$ interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\frac{\pi}{2}$ at point A and π at point B. Then the difference between resultant intensities at A and B is (IIT-JEE 2001)

(a) $2I$ (b) $4I$ (c) $5I$ (d) $7I$

16. In a double slit experiment instead of taking slits of equal widths, one slit is made twice as wide as the other, then in the interference pattern (IIT-JEE 2000)

(a) the intensities of both the maxima and the minima increases

(b) the intensity of the maxima increases and the minima has zero intensity

(c) the intensity of maxima decreases and that of minima increases

(d) the intensity of maxima decreases and the minima has zero intensity

17. A narrow slit of width 1 mm is illuminated by monochromatic light of wavelength 600 nm. The distance between the first minima on either side of a screen at a distance of 2 m is (IIT-JEE 1994)

(a) 1.2 cm (b) 1.2 mm (c) 2.4 cm (d) 2.4 mm

18. Two coherent monochromatic light beams of intensities I and $4I$ are superposed. The maximum and minimum possible intensities in the resulting beam are (IIT-JEE 1988)

(a) $5I$ and I (b) $5I$ and $3I$ (c) $9I$ and I (d) $9I$ and $3I$

19. In Young's double slit experiment, the separation between the slits is halved and the distance between the slits and the screen is doubled. The fringe width is (IIT-JEE 1981)

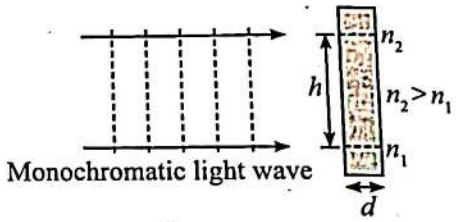
(a) unchanged (b) halved

(c) doubled (d) quadrupled

Multiple Correct

20. A monochromatic light wave is incident normally on a glass slab of thickness d, as shown in the figure. The refractive index of the slab increases linearly from n_1 to n_2 over the height h. Which of the following statement (s) is/are true about the light wave emerging out of the slab?

C-14.02 W-18.95 UA-53.36 PC-13.67 (JEE Adv. 2023)



(a) It will deflect up by an angle $\tan^{-1}\left[\frac{(n_2^2 - n_1^2)d}{2h}\right]$

(b) It will deflect up by an angle $\tan^{-1}\left[\frac{(n_2 - n_1)d}{h}\right]$

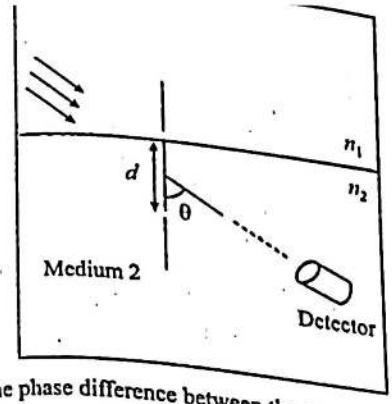
(c) It will not deflect.

(d) The deflection angle depends only on $(n_2 - n_1)$ and not on the individual values of n_1 and n_2.

21. A double slit setup is shown in the figure. One of the slits is in medium 2 of refractive index n_2. The other slit is at the interface of this medium with another medium 1 of refractive index $n_1 (\neq n_2)$. The line joining the slits is perpendicular to the interface and the distance between the slits is d. The slit widths are much smaller than d. A monochromatic parallel beam of light is incident on the slits from medium 1. A detector is placed in medium 2 at a large distance from the slits, and at an angle θ from the line joining them, so that θ equals the angle of refraction of the beam. Consider two approximately parallel rays from the slits received by the detector.

C-2.92 W-30.4 UA-58.95 (JEE Adv. 2022)

@JEE_CBSE_X @RK_EDUNET



(a) The phase difference between the two rays is independent of d.

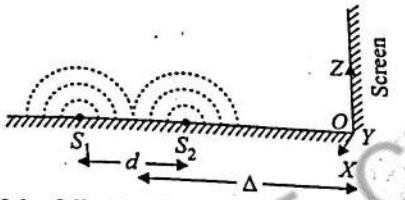
(b) The two rays interfere constructively at the detector.

(c) The phase difference between the two rays depends on n, but is independent to n_2.

(d) The phase difference between the two rays vanishes only for certain values of d and the angle of incidence of the beam, with θ being the corresponding angle of refraction.

22. While conducting Young's double slit experiment, a student replaced the two slits with a large opaque plate in the x-y plane containing two small holes that act as two coherent point sources (S_1, S_2) emitting light of wavelength 600 mm. The student mistakenly placed the screen parallel to the x-z plane (for $z > 0$) at a distance $D = 3$ m from the mid-point of S_1S_2, as shown schematically in the figure. The distance between the source $d = 0.6003$ mm. The origin O is at the intersection of the screen and the line joining S_1S_2.

C-8.09 W-27.73 UA-49.21 PC-14.98 (JEE Adv. 2016)



Which of the following is/are true of the intensity pattern on the screen?

(a) Semi circular bright and dark bands centered at point O

(b) The region very close to the point O will be dark

(c) Straight bright and dark bands parallel to the X-axis

(d) Hyperbolic bright and dark bands with foci symmetrically placed about O in the x-direction

23. A light source, which emits two wavelengths $\lambda_1 = 400$ nm and $\lambda_2 = 600$ nm, is used in a Young's double-slit experiment. If recorded fringe widths for λ_1 and λ_2 are β_1 and β_2 and the number of fringes for them within a distance y on side of the central maximum are m_1 and m_2, respectively, then

C-27.13 W-67.06 UA-5.81 (JEE Adv. 2014)

(a) $\beta_2 > \beta_1$ (b) $m_1 > m_2$

(c) from the central maximum, 3rd maximum of λ_2 overlaps with 5th minimum of λ_1

(d) the angular separation of fringes of λ_1 is greater than λ_2

24. In a Young's double slit experiment, the separation between the two slits is d and the wavelength of the light is λ. The intensity of light falling on slit 1 is four times the intensity of light falling on slit 2. Choose the correct choice (s). **(IIT-JEE 2008)**

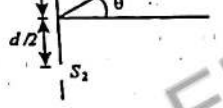
(a) If $d = \lambda$, the screen will contain only one maximum

(b) If $\lambda < d < 2\lambda$, at least one more maximum besides the central maximum) will be observed on the screen

(c) If the intensity of light falling on slit 1 is reduced so that it becomes equal to that of slit 2, the intensities of the observed dark and bright fringes will increase

(d) If the intensity of light falling on slit 2 is increased so that it becomes equal to that of slit 1 , the intensities of the observed dark and bright fringes will increase

25. In an interference arrangement similar to Young's double-slit experiment, the slits S_1 and S_2 are illuminated with coherent microwave sources, each of frequency 10^6 Hz. The sources are synchronized to have zero phase difference. The slits are separated by a distance $d = 150.0$ m. The intensity $I(\theta)$ is measured as a function of θ, where θ is defined as shown. If I_0 is the maximum intensity, then $I(\theta)$ for $0 \le \theta \le 90°$ is given by **(IIT-JEE 1995)**



(a) $I(\theta) = I_0/2$ = for $\theta = 30°$

(b) $I(\theta) = I_0/4$ for $\theta = 90°$

(c) $I(\theta) = I_0$ for $\theta = 0°$

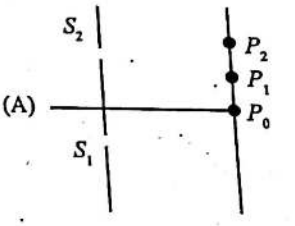
(d) $I(\theta)$ is constant for all values of θ

Match the Column

26. Column-I shows four situations of standard Young's double slit arrangement with the screen placed far away from the slits S_1 and S_2. In each of these cases $S_1P_0 = S_2P_0$, $S_1P_1 - S_2P_1 = \lambda/4$ and $S_1P_2 - S_2P_2 = \lambda/2$, where λ is the wavelength of the light used. In the cases B, C and D, a transparent sheet of refractive index μ and thickness t is pasted on slit S_2. The thickness of the sheets are different in different cases. The phase difference between the light waves reaching a point P on the screen from the two slits is denoted by $\delta(P)$ and the intensity by $I(P)$. Match each situation given in Column-I with the statement(s) in Column-II valid for that situation. **(IIT-JEE 2009)**

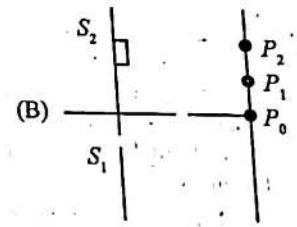
Column-I **Column-II**

(A)



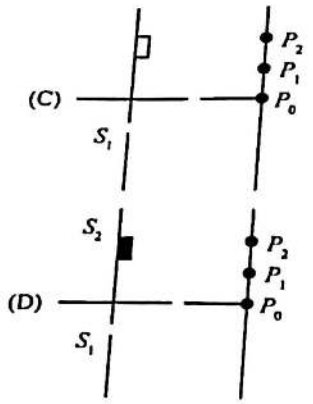
(p) $\delta(P_0) = 0$

(B)



(q) $\delta(P_1) = 0$

@FAKE_CBSE_X_@RAJ_EDUNET

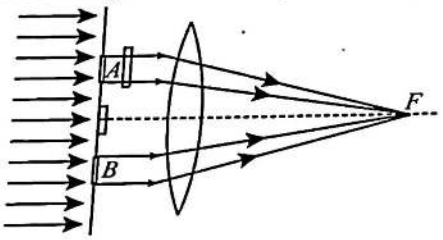


Numerical Types/Integer Types

27. In a Young's double slit experiment, two wavelengths of 500 nm and 700 nm were used. What is the minimum distance from the central maximum where their maxima coincide again? Take $D/d = 10^3$. Symbols have their usual meanings. **(IIT-JEE 2004)**

28. In a Young's experiment, the upper slit is covered by a thin glass plate of refractive index 1.4, while the lower slit is covered by another glass plate, having the same thickness as the first one but having refractive index 1.7. Interference pattern is observed using light of wavelength 5400 Å. It is found that the point P on the screen, where the central maximum ($n = 0$) fall before the glass plates were inserted, now has 3/4 the original intensity. It is further observed that what used to be the fifth maximum earlier lies below the point P while the sixth minima lies above P. Calculate the thickness of glass plate. (Absorption of light by glass plate may be neglected). **(IIT-JEE 1997)**

29. In a modified Young's double slit experiment, a monochromatic uniform and parallel beam of light of wavelength 6000 Å and intensity $(10/\pi)$ Wm^{-2} is incident normally on two apertures A and B of radii 0.001 m and 0.002 m respectively. A perfectly transparent film of thickness 2000Å and refractive index 1.5 for the wavelength of 6000Å is placed in front of aperture A (see figure). Calculate the power (in W) received at the focal spot F of the lens. The lens is symmetrically placed with respect to the apertures. Assume that 10% of the power received by each aperture goes in the original direction and is brought to the focal spot. **(IIT-JEE 1989)**



Fill in the Blanks

30. A slit of width d is placed in front of a lens of focal length 0.5 m and is illuminated normally with light of wavelength 5.89×10^{-7} m. The first diffraction minima on either side of the central diffraction maximum are separated by 2×10^{-3} m.

The width d of the slit is ..... m. **(IIT-JEE 1997)**

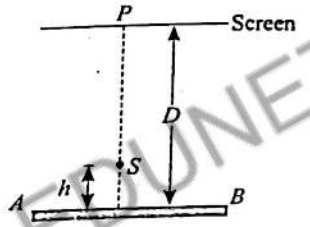
True/False

31. Two slits in a Young's double slit experiment are illuminated by two different sodium lamps emitting light of the same wavelength. No interference pattern will be observed on the screen. **(IIT-JEE 1984)**

32. In a Young's double slit experiment performed with a source of white light, only black and white fringes are observed. **(IIT-JEE 1987)**

Subjective

33. A point source S emitting light of wavelength 600 nm is placed at a very small height h above a flat reflecting surface AB (see figure). The intensity of the reflected light is 36% of the incident intensity. Interference fringes are observed on a screen placed parallel to the reflecting surface at a very large distance D from it. **(IIT-JEE 2002)**

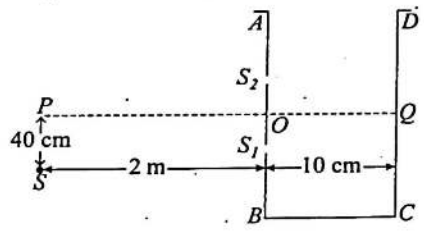


(a) What is the shape of the interference fringes on the screen?

(b) Calculate the ratio of the minimum to the maximum intensities in the interference fringes formed near the point P (shown in the figure).

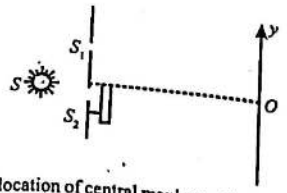
(c) If the intensity at point P corresponds to a maximum, calculate the minimum distance through which the reflecting surface AB should be shifted so that the intensity at P again becomes maximum.

34. A vessel $ABCD$ of 10 cm width has two small slits S_1 and S_2 sealed with identical glass plates of equal thickness. The distance between the slits is 0.8 mm. POQ is the line perpendicular to the plane AB and passing through O, the middle point of S_1 and S_2. A monochromatic light source is kept at S, 40 cm below P and 2 m from the vessel, to illuminate the slits as shown in the figure alongside. Calculate the position of the central bright fringe on the other wall CD with respect to the line OQ. Now, a liquid is poured into the vessel and filled upto OQ. The central bright fringe is found to be at Q. Calculate the refractive index of the liquid. **(IIT-JEE 2001)**



35. The Young's double slit experiment is done in a medium of refractive index 4/3. A light of 600 nm wavelength is falling on the slits having 0.45 mm separation. The lower slit S_2 is covered by a thin glass sheet of thickness 10.4 μm and refractive index 1.5. The interference pattern is observed on a screen placed 1.5 m from the slits as shown in the figure. **(IIT-JEE 1999)**

@RAJEDUNET

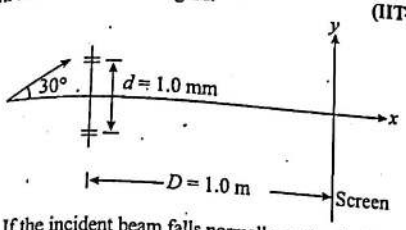


(a) Find the location of central maximum (bright fringe with zero path difference) on the y-axis.

(b) Find the light intensity of point O relative to the maximum fringe intensity.

(c) Now, if 600 nm light is replaced by white light of range 400 to 700 nm, find the wavelengths of the light that form maxima exactly at point O. (All wavelengths in the problem are for the given medium of refractive index 4/3. Ignore dispersion)

36. A coherent parallel beam of microwaves of wavelength $\lambda = 0.5$ mm falls on a Young's double slit apparatus. The separation between the slits is 1.0 mm. The intensity of microwaves is measured on a screen placed parallel to the plane of the slits at a distance of 1.0 m from it as shown in the figure. **(IIT-JEE 1998)**



(a) If the incident beam falls normally on the double slit apparatus, find the y-coordinates of all the interference minima on the screen.

(b) If the incident beam makes an angle of 30° with the x-axis (as in the dotted arrow shown in figure), find the y-coordinates of the first minima on either side of the central maximum.

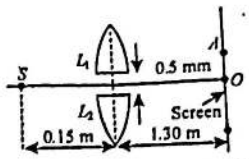
37. In Young's experiment, the source is red light of wavelength 7×10^{-7} m. When a thin glass plate of refractive index 1.5 at this wavelength is put in the path of one of the interfering beams, the central bright fringe shifts by 10^{-3} m to the position previously occupied by the 5th bright fringe. Find the thickness of the plate. When the source is now changed to green light of wavelength 5×10^{-7} m, the central fringe shifts to a position initially occupied by the 6th bright fringe due to red light. Find the refractive index of glass for green light. Also estimate the change in fringe width due to the change in wavelength. **(IIT-JEE 1997)**

38. A double slit apparatus is immersed in a liquid of refractive index 1.33. It has slit separation of 1 mm and distance between the plane of slits and screen is 1.33 m. The slits are illuminated by a parallel beam of light whose wavelength in air is 6300 Å .**(IIT-JEE 1996)**

(a) Calculate the fringe width.

(b) One of the slits of the apparatus is covered by a thin glasssheet of refractive index 1.53. Find the smallest thickness of the sheet to bring the adjacent minimum on the axis.

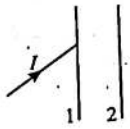
39. In given figure, S is a monochromatic point source emitting light of wavelength $\lambda = 500$nm. A thin lens of circular shape and focal length 0.10 m is cut into two identical halves L_1 and L_2 by a plane passing through a diameter. The two halves are placed symmetrically about the central axis SO with a gap of 0.5 mm. The distance along the axis from S to L_1 and L_2 is 0.15 m while that from L_1 and L_2 to O is 1.30 m. The screen at O is normal to SO. **(IIT-JEE 1993)**



(a) If the third intensity maximum occurs at the point A on the screen, find the distance OA.

(b) If the gap between L_1 and L_2 is reduced from its original value of 0.5 mm, will the distance OA increase, decrease, or remain the same.

40. A narrow monochromatic beam of light of intensity I is incident on a glass plate as shown in figure. Another identical glass plate is kept close to the first one-and parallel to it. Each glass plate reflects 25 per cent of the light incident on it and transmits the remaining. Find the ratio of the minimum and maximum intensities in the interference pattern formed by the two beams obtained after one reflection at each plate. **(IIT-JEE 1990)**



41. A beam of light consisting of two wavelengths, 6500Å and 5200 Å is used to obtain interference fringe in a Young's double slit experiment. **(IIT-JEE 1985)**

(a) Find the distance of the third bright fringe on the screen from the central maximum for wavelength 6500 Å.

(b) What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide?

The distance between the slits is 2 mm and the distance between the plane of the slits and the screen is 120 cm.

42. In Young's double slit experiment using monochromatic light the fringe pattern shifts by a certain distance on the screen when a mica sheet of refractive index 1.6 and thickness 1.964 microns is introduced in the path of one of the interfering waves. The mica sheet is then removed and the distance between the slits and the screen is doubled. It is found that the distance between successive maxima (or minima) now is the same as the observed fringe shift upon the introduction of the mica sheet. Calculate the wavelength of the monochromatic light used in the experiment. **(IIT-JEE 1983)**

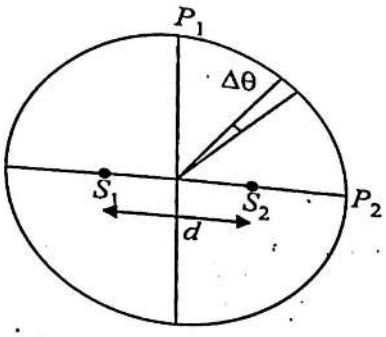
Lloyd's Mirror, Fresnel Biprism and Thin Film Interference

Multiple Correct

43. Two coherent monochromatic point sources S_1 and S_2 of wavelength $\lambda = 600$ nm are placed symmetrically on either side of the centre of the circle as shown. The sources are separated by a distance $d = 1.8$ mm. This arrangement produces interference fringes visible as alternate bright and dark spots on the circumference of the circle. The angular separation between two consecutive bright spots is $\Delta\theta$. Which of the following options is/are correct?

C-7.99 W-32.08 UA-48.51 PC-11.42 (JEE Adv. 2017)

@IITK_BOOK @RAJ_FDUNET



(a) The angular separation between two consecutive bright spots decreases as we move from P_1 to P_2 along the first quadrant

(b) A dark spot will be formed at the point P_2

(c) The total number of fringes produced between P_1 and P_2 in the first quadrant is close to 3000

(d) At P_2 the order of the fringe will be maximum

Subjective

44. In a Young's experiment, the upper slit is covered by a thin glass plate of refractive index 1.4, while the lower slit is covered by another glass plate, having the same thickness as the first one but having refractive index 1.7. Interference pattern is observed using light of wavelength 5400 Å. It is found that the point P on the screen, where the central maximum ($n = 0$) fall before the glass plates were inserted, now has 3/4 the original intensity. It is further observed that what used to be the fifth maximum earlier lies below the point P while the sixth minima lies above P. Calculate the thickness of glass plate. (Absorption of light by glass plate may be neglected). **(IIT-JEE 1997)**

45. Angular width of central maximum in the Fraunhofer diffraction pattern of a slit is measured. The slit is illuminated by light of wavelength 6000 Å. When the slit is illuminated by light of another wavelength, the angular width decreases by 30%. Calculate the wavelength of this light. The same decrease in the angular width of central maximum is obtained when the original apparatus is immersed in a liquid. Find refractive index of the liquid. **(IIT-JEE 1996)**

@FAKE_CBSE X @RAJ_EDUNET

ANSWER KEY

JEE-Main

1. (*d*)	**2.** (*a*)	**3.** [125]	**4.** (*a*)	**5.** [200]	**6.** [8]	**7.** [275]	**8.** [10]	**9.** [9]	**10.** [1]
11. (*c*)	**12.** (*c*)	**13.** (*a*)	**14.** (*c*)	**15.** (*b*)	**16.** [48]	**17.** [3]	**18.** [462]	**19.** (*b*)	**20.** (*d*)
21. [450]	**22.** [600]	**23.** (a, b)	**24.** (*b*)	**25.** (*c*)	**26.** (*c*)	**27.** (*b*)	**28.** (*b*)	**29.** [1.00]	**30.** [5]
31. [600]	**32.** [50.47]	**33.** (*d*)	**34.** (*a*)	**35.** (*c*)	**36.** (*c*)	**37.** (*a*)	**38.** [750]	**39.** (*c*)	**40.** (*)
41. (*a*)	**42.** (*b*)	**43.** (*d*)	**44.** (*d*)	**45.** (*b*)	**46.** (*a*)	**47.** (*c*)	**48.** [0.2]	**49.** [4]	**50.** (*c*)
51. [10]	**52.** [4]	**53.** (b, d)	**54.** (*b*)	**55.** (*a*)	**56.** [300]	**57.** [09]	**58.** (*a*)	**59.** (*b*)	**60.** (*c*)
61. (*b*)	**62.** (*a*)	**63.** (*a*)	**64.** (*a*)	**65.** [2]	**66.** (*d*)	**67.** [30.00]	**68.** [2]	**69.** [6]	**70.** (*b*)
71. (*b*)	**72.** (*b*)	**73.** (*c*)	**74.** [30, 60]	**75.** [7]	**76.** [24]	**77.** (*c*)	**78.** [3]	**79.** (*a*)	**80.** (*c*)
81. [30]	**82.** [75]	**83.** (*d*)	**84.** (*a*)	**85.** [198]	**86.** (*b*)	**87.** (*d*)			

JEE-Advanced

1. (*a*)	**2.** (*a*, *c*)	**3.** (*b*, *d*)	**5.** [True]	**6.** (*c*)	**7.** (*c*)	**8.** (*b*)	**9.** (*d*)	**10.** (*c*)	**11.** (*d*)
12. (*b*)	**13.** (*a*)	**14.** (*b*)	**15.** (*b*)	**16.** (*a*)	**17.** (*d*)	**18.** (*c*)	**19.** (*d*)	**20.** (*b*, *d*)	**21.** (*a*, *b*)
22. (*a*, *b*)	**23.** (*a*, *b*, *c*)	**24.** (*a*, *b*)	**25.** (*a*, *c*)	**26.** (A) $\rightarrow$(*p*, *s*), (B) $\rightarrow$(*q*), (C) $\rightarrow$(*t*), (D) $\rightarrow$(*r*,*s*,*t*)				**27.** [3.5]	**28.** [9.3]
29. [7×10^{-6}]	**31.** [True]	**32.** [False]	**43.** (*c*, *d*)						

...overed by a thin glass ... the lower slit is covered by ... same thickness as the first one but ... Interference pattern is observed which ... It is found that the point P on the screen ... ($n = 0$) fall before the glass plates were ... iginal intensity. It is further observed ... maximum earlier lies below the point ... s above P. Calculate the thickness of ... ght by glass plate may be neglected. (IIT-JEE 1997)

...imum in the Fraunhofer diffraction ... The slit is illuminated by light of ... slit is illuminated by light of another ... decreases by 30%. Calculate the ... ame decrease in the angular width ... ed when the original apparatus is ... ctive index of the liquid. (IIT-JEE 1996)

9] 10. [1]
b) 20. (d)
1.00] 30. [5]
:) 40. (*)
] 50. (c)
) 60. (c)
| 70. (b)
80. (c)

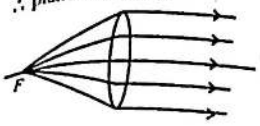
11. (d)
f) 21. (a, b)
] 28. [9.3]

EXPLANATIONS

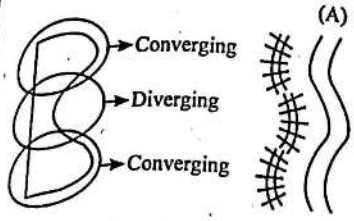
JEE-Main

1. *(d)* Light become parallel when passes through a convex lens.

$\therefore$ plane wavefront



2. *(a)*



3. **[125]** Let intensity of light on screen due to each slit is I_0 So intensity at centre of screen is $4I_0$ Intensity at distance y from centre-

$I = I_0 + I_0 + 2\sqrt{I_0 I_0}\cos\phi$

$I_{max} = 4I_0 \Rightarrow \frac{I_{max}}{2} = 2I_0 + 2I_0\cos\phi$

For $\phi = \frac{\pi}{2}$

$K\Delta x = \frac{\pi}{2}$

$\frac{2\pi}{\lambda} d\sin\theta = \frac{\pi}{2}$

$\frac{2}{\lambda} d \times \frac{y}{D} = \frac{1}{2}$

$y = \frac{\lambda D}{4d} = \frac{5\times10^{-7}\times1}{4\times10^{-3}} = 125\times10^{-6} = 125$

4. *(a)* Given the difference,

$\Delta x = \frac{7\lambda}{4}$

$\phi = \frac{2\pi}{\lambda}\Delta x = \frac{2\pi}{\lambda}\times\frac{7\lambda}{4} = \frac{7\pi}{2}$

$I = I_{max}\cos^2\left(\frac{\phi}{2}\right)$

The ratin of intensities

$\frac{I}{I_{max}} = \cos^2\left(\frac{\phi}{2}\right) = \cos^2\left(\frac{7\pi}{2\times2}\right) = \cos^2\left(\frac{7\pi}{4}\right)$

$= \cos^2\left(2\pi - \frac{\pi}{4}\right) = \cos^2\frac{\pi}{4} = \frac{1}{2}$

5. **[200]** According to law of malus,

$I = I_0\cos^2\left(\frac{\Delta\phi}{2}\right)$

$\frac{I_0}{4} = \cos^2\left(\frac{\Delta\phi}{2}\right)$

$\frac{2\pi}{\lambda}\left(\frac{yd}{D}\right) = \frac{2\pi}{3}$ $\left[\Delta\phi = \frac{2\pi}{3}\right]$

$\Rightarrow y = \frac{\lambda D}{3d}$

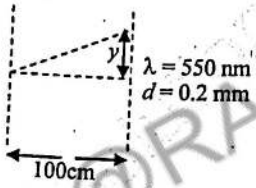
$= \frac{600\times10^{-9}\times1}{3\times10^{-3}} = 2\times10^{-4}\,m$

6. **[8]** $I_{min} = (\sqrt{4I} - \sqrt{I})^2 = I$

$I_{max} = (\sqrt{I} + \sqrt{4I})^2 = 9I$

$I_{max} - I_{min} = 8I$

7. **[275]**



$y = \frac{\lambda D}{d} = \frac{550\times10^{-9}\times100\times10^{-2}}{0.2\times10^{-3}}$

$= 275\times10^{-5}$ m

8. **[10]** Here, fringe width,

$\beta = \frac{\lambda D}{d} = \frac{5\times10^{-7}\times2}{3\times10^{-4}} = \frac{10\times10^{-3}}{3}$ m

For 3rd maxima $y_3 = \frac{3\lambda D}{d}$

$y_3 = 3\beta = 10\times10^{-3}$ m $= 10$ mm

9. **[9]** $n_1\lambda_1 = n_2\lambda_2$

$\frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1} = \frac{9}{13} = \frac{450}{650}$

$\therefore n_2 = 9$

10. **[1]** As, Intensity is directly proportional to with width of slit (w)

Therefore, $I_1 = I, I_2 = 4I$

$I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2 = I$

$I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 = 9I$

$\therefore \frac{I_{max}}{I_{min}} = \frac{9I}{I} = \frac{9}{1}$

11. *(c)* $A_2P - A_1P = \frac{\lambda}{2}$

(Condition of minima)

$\sqrt{D^2 + a^2} - D = \frac{\lambda}{2}$

$D\left(1 + \frac{a^2}{D^2}\right)^{1/2} - D = \frac{\lambda}{2}$

$D\left(1 + \frac{1}{2}\times\frac{a^2}{D^2}\right) - D = \frac{\lambda}{2}$

$\frac{a^2}{2D} = \frac{\lambda}{2}$

$\Rightarrow a = \sqrt{\lambda.D}$

$= \sqrt{800\times10^{-6}\times50}$

$a = 0.2\,mm$

12. *(c)* $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

$= I_0 + I_0 + 2I_0\cos\phi = 2I_0(1 - \cos\phi)$

For $\phi = \frac{\pi}{3} \Rightarrow I_P = 3I_0$

For $\phi = \frac{\pi}{2} \Rightarrow I_Q = 2I_0$

$\frac{I_P}{I_Q} = \frac{3I_0}{2I_0} = \frac{3}{2}$

13. *(a)* $\because$, $y_{n^{th}} = \frac{n\lambda D}{d}$

$\Rightarrow \frac{5\times600\times10^{-9}\times1}{d} = 5\times10^{-2}$

$\Rightarrow d = 60\mu m$

14. *(c)* Formula of fringe width $(\beta) = \frac{D\lambda}{d}$

$\Rightarrow \beta \propto \lambda$

$\therefore \Rightarrow \frac{\beta_2}{\beta_1} = \frac{\lambda_2}{\lambda_1} \Rightarrow \beta_2 = \frac{\lambda_2}{\lambda_1}\times\beta_1$

$\Rightarrow \beta_2 = \frac{600\,nm}{400\,nm}\times2mm \Rightarrow \beta_2 = 3mm$

15. *(b)* From the question, $\frac{A_1}{A_2} = \frac{2}{1}$

$I \propto$ (Amplitude)^2

$\frac{I_{max}}{I_{min}} = \left(\frac{A_1 + A_2}{A_1 - A_2}\right)^2 = \frac{9}{1} = 9:1$

16. **[48]** It is given,

Wavelength of 1st wave $\lambda_1 = 800$ nm

Wavelength of 2nd wave $\lambda_2 = 600$ nm

Distance of screen from the slit, $D = 7$ m

@FAKE_CBSE_X @RAJ_EDUNET

Distance between the two slits, $d = 0.35$ mm

$n_1 \frac{\lambda_1 D}{d} = n_2 \frac{\lambda_2 D}{d}$

$800 n_1 = 600 n_2 \Rightarrow \frac{n_1}{n_2} = \frac{3}{4}$

Minimum $n_1 = 3$ & $n_2 = 4$

Minimum separation $= \frac{n_1 \lambda_1 D}{d}$

$= \frac{3 \times 800 \text{ nm} \times 7 \text{ m}}{0.35 \text{ mm}} = 48$

17. **[3]** $\because I = 4I_0 \cos^2\left(\frac{\Delta\phi}{2}\right)$ and path difference $= \frac{\lambda}{2\pi} \times$ phase diff.

For path difference $\frac{\lambda}{4}$, phase difference $\phi = \frac{\pi}{2}$

$\Rightarrow I_1 = 4I_0 \cos^2\left(\frac{\pi}{4}\right) = 2I_0$

For path difference $\frac{\lambda}{3}$, path difference $\phi = \frac{2\pi}{3}$

$\Rightarrow I_2 = 4I_0 \cos^2\left(\frac{\pi}{3}\right) = I_0 \Rightarrow \frac{I_1 + I_2}{I_0} = 3$

18. **[462]** $d = 2.5$ mm, $D = 150$ cm

Fringe width $\beta = \frac{\lambda D}{d}$

Let n^{th} bright tringle of λ_1 match with m^{th} bright triangle of λ_2

$n\beta_1 = m\beta_2$

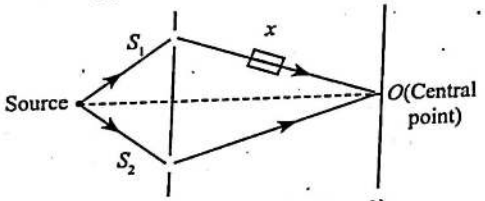
$\frac{n\lambda_1 D}{d} = \frac{m\lambda_2 D}{d} \Rightarrow \frac{n}{m} = \frac{\lambda_2}{\lambda_1} = \frac{5500}{7000} = \frac{11}{14}$

Distance where bright fringe will match

$= \frac{n\lambda \cdot D}{d}$

$= \frac{11 \times 7000 \text{ Å} \times 150 \text{ cm}}{0.25 \text{ cm}} = 462 \times 10^{-5}$

19. **(b)**



Path difference at $O = (\mu - 1)t$.

If the intensity at O remains unchanged.

$\Rightarrow (\mu - 1)t = n\lambda$

$(1.5 - 1)x\lambda = n\lambda$

$\Rightarrow x = 2n$

For $n = 1$, $x = 2$

20. **(d)** Fringe width, $\beta = \frac{D\lambda}{d}$

$\lambda_1 = 5000$ Å

$\beta_1 = \frac{D}{d}(5000 \times 10^{-10}) = 5 \times 10^{-4}$ m ...(i)

$\beta_2 = \frac{D}{(2d)}(6000 \times 10^{-10}) = x$(let) ...(ii)

Divide (ii) and (i)

$\frac{\beta_2}{\beta_1} = \frac{3000 \times 10^{-10}}{5000 \times 10^{-10}} = \frac{x}{5 \times 10^{-4}}$

$x = 3 \times 10^{-4}$ m or 0.3 mm

21. **[450]** $d = 0.6$ mm

D = 80 cm = 800 mm

For first dark fringe

$\frac{D\lambda}{2d} = \frac{d}{2} \Rightarrow \lambda = \frac{d^2}{D}$

$\lambda = \frac{(0.6)^2}{800}$

$\lambda = 450$ mm

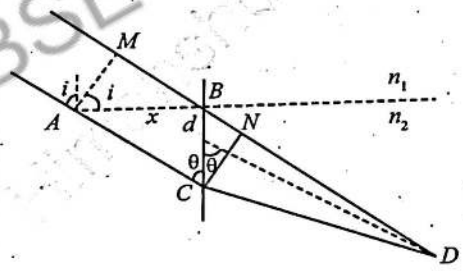
22. **[600]** $\beta = \frac{\lambda D}{d}$

$\Delta\beta = \frac{\lambda}{d}\Delta D$

$\lambda = \frac{\Delta\beta . d}{\Delta D} = \frac{3 \times 10^{-5} \times 1 \times 10^{-3}}{5 \times 10^{-2}}$

$= 60 \times 10^{-8} = 600 \times 10^{-9}$ m = 600 nm

23. **(a, b)** Path difference



$\Delta r = (MB + BN) - AC$

$\Delta r = (n_1 x \sin i + n_2 d\cos\theta) - \frac{n_2 d}{\cos\theta}$

$\Delta r = n_1(d\tan\theta)\frac{n_2}{n_1}\sin\theta + n_2 d\cos\theta - \frac{n_2 d}{\cos\theta}$

$(\because x = d\tan\theta; n_1 \sin i = n_2 \sin\theta)$

$\Delta r = \frac{n_2 d\sin^2\theta}{\cos\theta} + n_2 d\cos\theta - \frac{n_2 d}{\cos\theta}$

$\Delta r = \frac{n_2 d\left[\sin^2\theta + \cos^2\theta - 1\right]}{\cos\theta} = 0$

$\therefore \Delta\phi = \frac{2\pi}{\lambda}\Delta r = 0$

24. **(b)** $y_n = \frac{n\lambda D}{d}$

$\therefore 2\beta = \frac{2\lambda D}{d}$

$= 2 \times 5890 \times 10^{-10} \times \frac{0.5}{(0.5 \times 10^{-3})}$

$= 1178 \times 10^{-6}$ m

25. **(c)** The fringe separation

$\beta = \frac{\lambda D}{d} = \frac{500 \times 10^{-9} \times 1}{2 \times 10^{-3}}$

$= 250 \times 10^{-6}$ m $= 250 \times 10^{-3}$ mm $= 0.25$ mm

26. **(c)** $\beta = \frac{\lambda D}{d} \frac{\lambda D}{d_0 + a_0 \sin\omega t}$

For the largest fringe width, $\sin\omega t = -1$

For the smallest fringe width, $\sin\omega t = +1$

$\therefore$ Difference between the largest to smallest fringe width $= \beta_1 - \beta_2$.

$\beta_1 - \beta_2 = \frac{\lambda D}{d_0 - a_0} - \frac{\lambda D}{d_0 + a_0}$

$= \lambda D\left[\frac{(d_0 + a_0) - (d_0 - a_0)}{d_0^2 - a_0^2}\right] = \frac{2\lambda D a_0}{d_0^2 - a_0^2}$

27. **(b)** We know that,

$\beta = \frac{\lambda D}{d}$ and $\lambda_{Red} > \lambda_{violet}$

Therefore, if the source of light used in a Young's double slit experiment is changed from red to violet fringe width decreases and fringe lines will come cluse.

28. **(b)** Given, Amplitude, A $\propto$ slit width.

We know that,

Intencity, $I \propto (A)^2$

Here, $A_1 = 3A_2$

$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I_1} + \sqrt{I_2}}{\sqrt{I_1} - \sqrt{I_2}}\right)^2$

$= \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} = \frac{\left(\frac{A_1}{A_2} + 1\right)^2}{\left(\frac{A_1}{A_2} - 1\right)^2} = \frac{(3+1)^2}{(3-1)^2} = 4.$

29. **[1.00]** Given: Amp. α slit width

This impies intensity α(Amp)^2 α(slit width)^2

$\frac{I_1}{I_2} = \left(\frac{3}{1}\right)^2 = \frac{9}{1} \Rightarrow I_1 = 9I_2$

$\frac{I_{min}}{I_{max}} = \frac{(\sqrt{I_1} - \sqrt{I_2})^2}{(\sqrt{I_1} + \sqrt{I_2})} = \frac{(3-1)^2}{(3+1)^2}$

$\Rightarrow \frac{1}{4} = \frac{x}{4}$

$\therefore x = 1.00$

@FAKE_CBSE_X_@RAJ_EDUNET

30. [5] Position of 4th bright fringe from central maxima $= \frac{4\lambda D}{d}$

As distance between 4th bright fringe on both sides of central bright fringe is x

$= \frac{8\lambda D}{d}$

So, 2.4×10^{-2}

$= \frac{8\lambda(1.5)}{0.3\times10^{-3}} \Rightarrow \lambda = 6\times10^{-7}$ m

Hence, $f = \frac{c}{\lambda} = \frac{3\times10^{8}}{6\times10^{-7}} = 5\times10^{14}$ Hz

31. [600]

$\beta = \frac{\lambda D}{d} \Rightarrow \lambda = \frac{\beta d}{D} = \frac{6\times10^{-3}\times1\times10^{-3}}{10} = 6\times10^{-7}$ m

$= 600$nm

32. [50.47]

$\frac{1}{2}mv^2 = E$

$\Rightarrow P = \sqrt{2Em}$ $\quad \therefore \lambda = \frac{h}{\sqrt{2Em}}$

For first maxima,

$2d \sin\theta = \lambda$

$\Rightarrow 2\times10^{-10}\times\frac{\sqrt{3}}{2} = \frac{h}{\sqrt{2Em}}$

$\Rightarrow 2Em = \frac{(10^{10}\times h)^2}{3}$

$\Rightarrow E = \frac{(10^{10}\times h)^2}{6m_e\times e}(eV)$

$\Rightarrow E = 50.47\ eV$

33. (*d*) We know that, at any point intensity

$I = I_0\cos^2\left(\frac{\Delta\phi}{2}\right)$

Ratio of the intensity of light at that point of the centre of a bright fringe

$\frac{I}{I_0} = \cos^2\left[\frac{\frac{2\pi}{\lambda}\times\Delta x}{2}\right] = \cos^2\left(\frac{\pi}{8}\right) = 0.853$

34. (*a*) P.D. $= (d)\sin\theta$

$= \frac{Y}{D} = \frac{(10^{-3})(1.27\times10^{-3})}{1} = 1.27\ \mu$m

35. (*c*) $\theta = \frac{\lambda}{d} = \frac{500\times10^{-9}}{5\times10^{-5}} = 0.01$ rad $= 0.57°$

36. (*c*) $\beta = \frac{\lambda D}{d} = \frac{589\times10^{-9}\times1.5}{0.15\times10^{-3}} = 5.9$mm

37. (*a*) $N_1\lambda_1 = N_2\lambda_2$

$16\times700 = N_2\times400 \Rightarrow N_2 = 28$

38. [750] We will use the formula,

$\frac{n_1\lambda_1 D}{d} = \frac{n_2\lambda_2 D}{d}$

[D is the distance from the screen to the slits and d is the separation between the slits.]

$15\times500\times\frac{D}{d} = 10\times\lambda_2\times\frac{D}{d}$

$\lambda_2 = 15\times50$ nm

$\lambda_2 = 750$ nm

Hence, value of λ is 750.

39. (*c*) $\phi_A = \frac{\pi}{2} - \frac{2\pi}{\lambda}\times\frac{5}{20} = 0$

$\phi_B = \frac{\pi}{2}$

$\phi_C = \frac{\pi}{2} + \frac{2\pi}{\lambda}\times\frac{5}{20} = \pi$

$I_A = 4I_0$

$I_B = 2I_0$

$I_C = 0$

40. (*) Path difference at central maxima $\Delta x = (\mu-1)t$, whole pattern will shift by same amount which will be given by

$(\mu-1)t\ \frac{D}{d} = n\frac{\lambda D}{d}$,

according to the question

$t = \frac{n\lambda}{(\mu-1)}$

No option is matching

41. (*a*) $\sqrt{(2d)^2+(d)^2} - 2d = \frac{\lambda}{2}$

$\Rightarrow (\sqrt{5}-2)d = \frac{\lambda}{2} \Rightarrow d = \frac{\lambda}{2(\sqrt{5}-2)}$

42. (*b*) $\Delta x = \frac{\lambda}{8}$

Phase $|\Delta\phi| = \frac{2\pi}{\lambda}\times\frac{\lambda}{8} = \frac{\pi}{4}$

$\therefore I_{res} = I + I + 2I\cos\left(\frac{\pi}{4}\right)$

$= 2I\left(1+\frac{1}{\sqrt{2}}\right) = 2I\times1.7$

$\therefore \frac{I_{res}}{I_{max}} = \frac{2I\times1.7}{4I} = 0.85$

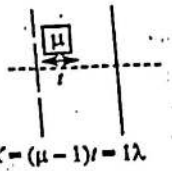
43. (*d*) $\Delta X_{mass} = d\sin\theta = 0.32\sin30 = 0.16$ mm

$\therefore n = \frac{\Delta X_{mass}}{\lambda} = \frac{0.16\times10^{-3}}{500\times10^{-9}}$

$= \frac{0.16\times10^{6}}{500} = \frac{1600}{5}$

$\therefore$ Number of BFs $= (2n+1) = 641$.

44. (*d*)



$\Delta X = (\mu-1)t = 1\lambda$

For one maximum shift $t = \frac{\lambda}{\mu-1}$

45. (*b*) $I_1 = 4I_0$

$I_2 = I_0$

$I_{max} = (\sqrt{I_1}+\sqrt{I_2})^2 = (2\sqrt{I_0}+\sqrt{I_0})^2 = 9I_0$

$I_{min} = (\sqrt{I_1}-\sqrt{I_2})^2 = (2\sqrt{I_0}-\sqrt{I_0})^2 = I_0$

$\therefore \frac{I_{max}}{I_{min}} = \frac{9}{1}$

46. (*a*) $\sqrt{(2d)^2+(d)^2} - 2d = \frac{\lambda}{2}$

$\Rightarrow (\sqrt{5}-2)d = \frac{\lambda}{2} \Rightarrow d = \frac{\lambda}{2(\sqrt{5}-2)}$

47. (*c*) (1) $\Delta x = d\sin\alpha = d\alpha$ (as α is very small)

For $\alpha = \frac{0.36}{180} = (2\times10^{-3})$rad

$\frac{\Delta x}{\lambda} = \frac{(3\times10^{-4})(2\times10^{-3})}{6\times10^{-7}} = 1$

$\left[\because \phi = \frac{2\pi}{\lambda}(\Delta x)\right]$

so constructive interference

(2) $\beta = \frac{D\lambda}{d}$

(3) $\Delta x_p = d\alpha + \frac{dy}{D}$

$= 3\times10^{-4}(2\times10^{-3}+11\times10^{-3})$

$= 39\times10^{-7}$

$\frac{\Delta x_p}{\lambda} = \frac{39\times10^{-7}}{6\times10^{-7}} = 6.5$ so destructive

(4) $\Delta x_p = \frac{dy}{D} = (3\times10^{-4})\times11\times10^{-3}$

$= 33\times10^{-7}$

$\frac{\Delta x_p}{\lambda} = \frac{33\times10^{-7}}{6\times10^{-7}} = 5.5 \Rightarrow$ destructive

48. [0.2] Given wavelength of light $= 400$ nm

$D = 0.2$ m

$2\sqrt{D^2+d^2} - 2D = \frac{\lambda}{2}$

$\therefore \sqrt{D^2+d^2} = \frac{\lambda}{4} + D$

$\Rightarrow D^2 + d^2 = D^2 + \frac{\lambda^2}{16} + \frac{D\lambda}{2}$

$\Rightarrow d^2 = \frac{D\lambda}{2} + \frac{\lambda^2}{16}$

@FAKE_CBSE_X @RAJ_EDUNET

$$\Rightarrow d^2 = \frac{0.2\times400\times10^{-9}}{2} + \frac{4\times10^{-14}}{4}$$

$$\Rightarrow d^2 \approx 400\times10^{-10} \Rightarrow d = 0.20 \text{ mm}$$

49. **[4]** $(\mu-1)\,t = n\lambda$

Putting, the values of λ and n we get,

$(1.5-1)t = 4\times500\times10^{-9}$ m

$t = 4000\times10^{-9}$ m $\Rightarrow t = 4\times10^{-6}$m

$t = 4\mu$m

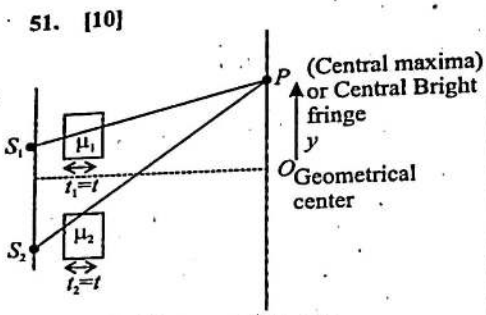
50. *(c)* As indices of refraction changes, wavelength change. And as medium changes, optical path changes.

$\because$ Path difference

$= \frac{\lambda}{2\pi}\times$ Phase difference

So phase difference changes.

51. **[10]**



Path difference at P be Δx

$\Delta x = (\mu_2-\mu_1)t = (1.55-1.51)0.1\text{mm}$

$= 0.04\times10^{-4}$

$\Delta x = 4\times10^{-6} = 4\mu m$

$y = \frac{\Delta x D}{d} = 4\times10^{-6}\frac{D}{d}$

{y is the distance of central maxima from geometric center}

fringe width $(\beta) = \frac{\lambda D}{d} = 4\times10^{-6}m\frac{D}{d} = 4\mu m\frac{D}{d}$

$\therefore$ Central bright fringe spot will shift by 'x'

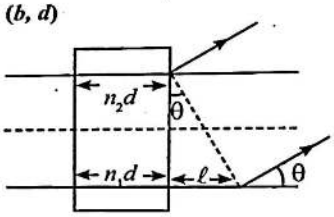
Number of shift $= \frac{y}{\beta}$

$= \frac{4\times10^{-6}D/d}{4\times10^{-7}D/d} = 10$

52. **[4]** Fringe shift $= \frac{t(\mu-1)}{\lambda}\beta_o$

$= \frac{10\times10^{-6}(1.2-1)}{5\times10^{-7}}\beta_o = 4\beta_o$

53. *(b, d)*



$n_1d + \ell = n_2d \Rightarrow \ell = (n_2-n_1)d$

Deflection angle; $\tan\theta = \frac{\ell}{h} = \frac{(n_2-n_1)d}{h}$

$\theta = \tan^{-1}\frac{(n_2-n_1)d}{h}$

depends on (n_2-n_1)

54. *(b)* $\beta = 12\text{mm} = 12\times10^{-3}$ m

Formula of fringe width

$\beta = \frac{\lambda D}{d}$

Wavelength with respect to medium

$\lambda' = \frac{\lambda}{\mu}$

Fringe width in medium,

$\beta' = \frac{\lambda' D}{d} = \frac{\lambda D}{\mu d}$

$\beta' = \frac{\beta}{\mu} = \frac{12\times10^{-3}}{\frac{4}{3}} = 9\times10^{-3}$ m

$\beta' = 9$ mm

55. *(a)* $\beta = \frac{\lambda D}{d}$

From formula, fringe width is directly proportional to wavelength and wavelength of orange light is greater than the blue light therefore,

So, $\beta_{Orange} > \beta_{Blue}$

Hence, distance between consecutive fringes will decrease.

56. **[300]** For first fringe of Red wavelength

$\frac{dy_1}{D} = 1\times\lambda_1$ $\quad [n=1]$

For first fringe of violet wavelength

$\frac{dy_2}{D} = 1\times\lambda_2$ $\quad [n=1]$

$\frac{d}{D}(y_1-y_2) = \lambda_1-\lambda_2$

$y_1-y_2 = \frac{D}{d}(\lambda_1-\lambda_2)$

$= \frac{0.3\times10^{-3}}{1.5}(3.5-2)\times10^{-3}$

$= 300\times10^{-9} = 300$ nm

57. **[09]** $\phi = \frac{2\pi}{\lambda}\times\frac{\lambda}{6} = \frac{\pi}{3}$

$I = k\cos^2\left(\frac{\phi}{2}\right) = \frac{3K}{4}$

$n = 9$

58. *(a)* $R = \frac{mv}{qB} = \frac{\sqrt{2m(K.E.)}}{qB}$

$R = \frac{\sqrt{2\times9.1\times10^{-31}\times(100\times1.6\times10^{-19})}}{1.6\times10^{-19}\times1.5\times10^{-3}}$

$R = 2.248$ cm

$\sin\theta = \frac{2}{2.248} = 0.89$

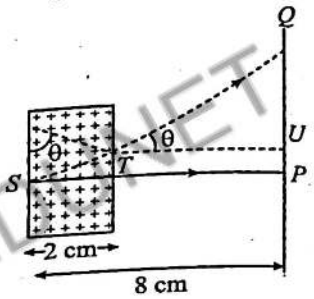
$\tan\theta = \frac{QU}{TU}$

$\frac{2}{1.026} = \frac{QU}{6}$

$QU = 11.69$

$PU = R(1-\cos\theta) = 1.22$

$d = QU + PU \simeq 12.9$ cm



59. *(b)* For diffraction

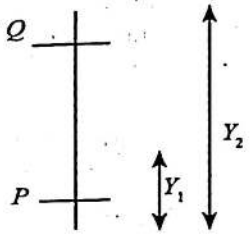
Location of 1st minima

$y_1 = \frac{D\lambda}{a} = 0.2469D\lambda$

Location of 2nd minima

$y_2 = \frac{2D\lambda}{a} = 0.4938D\lambda$

Now for interference



Path for interference

Path difference at P

$\frac{dy}{D} = 4.8\lambda$

Path difference at P.

$\frac{dy}{D} = 9.6\lambda$

So orders of maxima in between P and Q is

5, 6, 7, 8, 9

So 5 bright fringes all present between P and Q.

@FAKE_CBSE_RAJ_EDUNET

60. (c) $a\sin\theta = \lambda$ [For first minima]

$\boxed{\sin\theta = \frac{\lambda}{a} = \frac{1}{2}} \Rightarrow \theta = 30°$

61. (b) Linear width of the central maximum,

$$W = \frac{2\lambda d}{a} = \frac{2\times 6\times 10^{-7}\times 0.2}{1\times 10^{-5}}$$

$= 2.4 \times 10{-}2 = 24$ mm

62. (a) As we know, Width of 1st secondary maxima $= \frac{\lambda}{a}\cdot D$

Here, $a = 0.2 \times 10^{-3}$ m

$\lambda = 400 \times 10^{-9}$ m

$D = 100 \times 10^{-2}$

Hence, Width of 1st secondary maxima

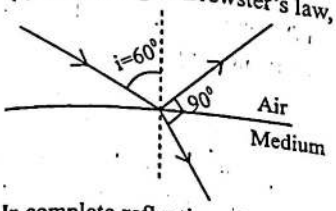
$= \frac{400\times 10^{-9}}{0.2\times 10^{-3}} \times 100\times 10^{-2} = 2$ mm

63. (a) Angle between plane and polaroid $A = 45°$

Intensity of emergent light

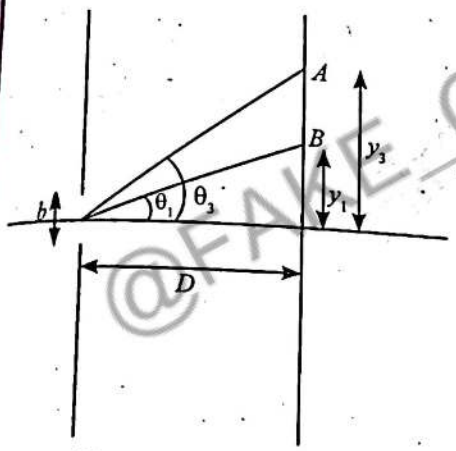
$\frac{I_0}{2}\cos^2 45° = \frac{I_0}{4}$

64. (a) According to Brewster's law,



In complete reflection, the refracted ray and the reflected ray are perpendicular to each other.

65. [2]



Given, wavelength of light = 6000 Å

Distance between 1st and 3rd minima = 3 mm

D = 50 cm

for n^{th} minima

$b\sin\theta = n\lambda$

(λ is small so $\sin\theta$ is small, hence $\sin\theta \approx \tan\theta$ $b\tan\theta = n\lambda$)

$b\frac{y}{D} = n\lambda \Rightarrow y_n = \frac{n\lambda D}{b}$

(Position of n^{th} minima)

$B \rightarrow 1^{st}$ minima, $A \rightarrow 3^{rd}$ minima

$y_3 = \frac{3\lambda D}{b}, y_1 = \frac{\lambda D}{b}$

$\Delta y = y_3 - y_1 = \frac{2\lambda D}{b}$

$3\times 10^{-3} = \frac{2\times 6000\times 10^{-10}\times 0.5}{b}$

$b = 2\times 10^{-4}$ m

$x = 2$

66. (d) I_1 = Intensity of light transmitted from 1st Polaroid $= \frac{I_0}{2}$, where as let I_0 be intensity of unpolarised light incident on first Polaroid.

θ be the angle between 1st and 2nd polaroid and ϕ be the angle between 2nd and 3rd polaroid $\phi = 90° - \theta$ (as 1st and 3rd polaroid are crossed)

I_2 = Intensity from 2nd polaroid $= I_1\cos^2\theta = \frac{I_0}{2}\cos^2\theta$

I_3 = Intensity from 3rd polaroid $= I_2\cos^2\phi$

$I_3 = I_1\cos^2\theta\cos^2\phi$

$I_3 = \frac{I_0}{2}\cos^2\theta\cos^2\phi$ [As $\phi = 90 - \theta$]

$I_3 = \frac{I_0}{2}\cos^2\theta\sin^2\theta$

$I_3 = \frac{I_0}{2}\left[\frac{2\sin\theta\cos\theta}{2}\right]^2 = \frac{I_0}{8}\sin^2 2\theta$

I_3 will be maximum when $\sin 2\theta = 1$

$2\theta = 90° \Rightarrow \theta = 45°$

67. [30.00] For first minima $\text{Sin}\theta = \frac{\lambda}{a}$

$\Rightarrow = \frac{5000\times 10^{-10}}{1\times 10^{-6}} = \frac{1}{2} \Rightarrow \theta = 30$

68. [2] Here given that,

$d = 1$ mm, $D = 1$m, $\lambda = 500$ nm

Position of central maxima = Width of central maxima in diffraction

$10\left(\frac{\lambda D}{d}\right) = \frac{2\lambda D}{a}$

$a = \frac{d}{5} = 2\times 10^{-4}$

69. [6] Since θ is very small so,

$\sin\theta = \theta = \frac{2\lambda}{b}$

$= \frac{2\times 600\times 10^{-9}}{4\times 10^{-4}} = 3\times 10^{-3}$ rad

Total divergence

$= (3+3)\times 10^{-3} = 6\times 10^{-3}$ rad

70. (b) Particle nature of light demonstrated by photo electric effect.

71. (b) Intensity of light after passing through the first sheet

$I_1 = \frac{I}{2}$

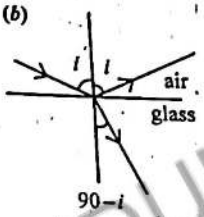
Intensity of light after passing through the second sheet

$I_2 = I_1\cos^2(45°) = \frac{I}{4}$

After passing through n^{th} sheet

$I_n = \frac{I}{2^n} = \frac{I}{64} \Rightarrow n = 6$

72. (b)



Using snell's law,

$\mu_a\sin i_1 = \mu_g\sin(90 - i_1)$

$\Rightarrow \tan i_1 = \frac{\mu_g}{\mu_a}$

For the ray going from glass to air

$\tan i_2 = \frac{\mu_a}{\mu_g} = \cot i_1$

$\Rightarrow i_2 = \frac{\pi}{2} - i_1$

73. (c) Intensity of light after passing through the polariser $I_A = \frac{I_o}{2}$

Intensity of light after passing through the polariserc

$I_C = \frac{I_o}{2}\cos^2 45 = \frac{I_o}{4}$

$\Rightarrow I_B = I_C\cos^2 45 = \frac{I_o}{8}$

74. [30, 60]

$I_o \xrightarrow{1^{st}} \frac{I_0}{2} \xrightarrow{2^{st}} \frac{I_0}{2}\cos^2\theta$

$\xrightarrow{3^{st}} \frac{I_0}{2}\cos^2\theta.\sin^2\theta$

$I_{Final} = \frac{32}{2}\cos^2\theta\cdot\sin^2\theta$ ($I_0 = 32\omega m^{-2}$)

$\frac{3}{4} = 4\sin^2\theta\cdot\cos^2\theta = (\sin 2\theta)^2$

$\frac{\sqrt{3}}{2} = \sin(2\theta) \Rightarrow \theta = 30°$ and $60°$.

@FAKE_CBSE_X @RAJ_EDUNET

75. [7] $\Rightarrow \tan i = \frac{\mu_2}{\mu_1} = \sqrt{\frac{6.8}{2.8}}$

$$\tan i = \left(\frac{2.8+4}{2.8}\right)^{1/2}$$

$$\Rightarrow i = \tan^{-1}\left(1+\frac{10}{7}\right)^{1/2} \Rightarrow \theta = 7$$

76. [24] After passing through the first polaroid, intensity of the light is halved $= \frac{256}{2}$

Polaroid P_2 and P_3 will make intensity $\cos^2(60°)$ and $\cos^2(30°)$ times respectively.

$\Rightarrow$Intensity of light point O

$$= \frac{256}{2} \times \frac{1}{4} \times \left(\frac{\sqrt{3}}{2}\right)^2 = 24$$

77. (c) $I = I_0 \cos^2 30°$

$$= I_0\left(\frac{\sqrt{3}}{2}\right)^2 = \frac{3}{4} I_0$$

78. [3] $a \sin\theta = \frac{3\lambda}{2}$

$$\frac{y}{L} = \theta = \frac{3\lambda}{2}$$

$$y_1 = \frac{3\lambda_1 L}{2a}$$

And,

$$y_2 = \frac{3\lambda_2 L}{2a}$$

$$\Delta y = y_2 - y_1 = \frac{3(\lambda_2 - \lambda_1)}{2a} L = 3 \times 10^{-5}$$

79. (a) Resolving Power, $R_P \propto \frac{1}{\lambda}$

As $\lambda = \frac{h}{P} = \frac{h}{mv}$

$\therefore R_P \propto mv \Rightarrow R_P \propto P$

$R_P \propto m$

Therefore, $\frac{R_{P_e}}{R_{P_a}} = 1837$

80. (c) We know that, $\sin\theta = \frac{n\lambda}{a}$

if $a\uparrow \rightarrow \theta\downarrow$

So width decrease as a result intensity increases.

81. [30] Using Malus Law, we get,

$$\frac{I}{2}\cos^2\theta = \frac{3I}{8}$$

$$\Rightarrow \cos\theta = \frac{\sqrt{3}}{2} \Rightarrow \theta = 30°$$

Hence, $\theta = 30°$ is the correct answer.

82. [75] Using Malus' law,

$I = I_0 \cos^2\theta = 100 \times \cos^2(30°) = 75$ Lumens

83. (d) $I = I_0 \cos^2\theta$

$$\frac{I_0}{10} = I_0 \cos^2\theta$$

$\cos\theta = \frac{1}{\sqrt{10}} = 0.31$ which is 0.707

So $\theta > 45°$ and $90 - \theta < 45°$ so only one option i.e. 18.4°

Angel rotated should be $= 90° - 71.6°$

$= 18.4°$

84. (a) For 2nd minima

$d \sin\theta = 2\lambda$

$\sin\theta = \frac{\sqrt{3}}{2}$ (given)

$\Rightarrow \frac{\lambda}{d} = \frac{\sqrt{3}}{4}$ ...(i)

So for 1st minima is

$d \sin\theta = \lambda$

$\sin\theta = \frac{\lambda}{d} = \frac{\sqrt{3}}{4}$ (from equation (i))

$\theta = 25.65°$ (from sin table)

$\theta \approx 25°$

85. [198] For minima $d \sin\theta = na$

$\Rightarrow$ for n to be maximum $\sin\theta = 1$

$$\Rightarrow n = \frac{6\times10^{-5}}{6\times10^{-7}} = 100$$

Since $n = 100$ will corresponds to infinity.

So number of minima possible in one side is 99 And in both side it is 198

86. (b) $I = I_0 \cos^2(\omega t) \Rightarrow I_{av} = \frac{I_0}{2}$

$$\therefore E = \frac{I_0}{2} \times A \times (\Delta t)$$

$$\Delta t = \frac{2\pi}{\omega} = \frac{2\times3.14}{31.4} = \frac{1}{5}\text{s}$$

$$\therefore E = \frac{3.3}{2} \times 3\times10^{-4} \times \frac{1}{5} = 1\times10^{-4}\text{ J}$$

87. (d) Since unpolarised light falls on $P_1 \Rightarrow$ intensity of light transmitted from $P_1(I_1) = \frac{I_0}{2}$

$\therefore$ Intensity of light transmitted form P_2

$$I_2 = \frac{I_0}{2}\cos^2 30° = \frac{3I_0}{8}$$

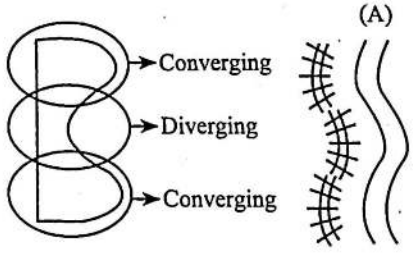
Intensity of light transmitted from P_3 is

$I = I_2 \cos(60°)^2$

$$\Rightarrow I = \frac{3I_0}{8} \times \frac{1}{4} \Rightarrow \frac{I_0}{I} = \frac{32}{3} = 10.67$$

JEE-Advanced

1. (a)



2. (a,c) At P (directly in front of S_1) $y = b/2$

$\therefore$ Path difference,

$$\Delta X = S_2P - S_1P = \frac{y\cdot(b)}{d} = \frac{\frac{b}{2}(b)}{d} = \frac{b^2}{2d}$$

Those wavelengths will be missing for which

$$\Delta X = \frac{\lambda_1}{2}, \frac{3\lambda_2}{2}, \frac{5\lambda_3}{2} \ldots$$

$$\therefore \lambda_1 = 2\Delta x = \frac{b^2}{d} \Rightarrow \lambda_2 = \frac{2\Delta x}{3} = \frac{b^2}{3d}$$

$$\lambda_3 = \frac{2\Delta x}{5} = \frac{b^2}{5d}$$

3. (b, d)

$$\frac{I_{max}}{I_{min}} = \frac{\left(\sqrt{I_1}+\sqrt{I_2}\right)^2}{\left(\sqrt{I_1}-\sqrt{I_2}\right)^2} = \left(\frac{\sqrt{I_1/I_2}+1}{\sqrt{I_1/I_2}-1}\right)^2 = 9$$

(Given)

Solving this, we have $\frac{I_1}{I_2} = 4$ but $I \propto A^2$

$$\therefore \frac{A_1}{A_2} = 2$$

$\therefore$Correct options are (b) and (d).

4. In case of YDSE, at mid-point intensity will be $I_{max} = 4I_0$ In the second case when sources are incoherent, the intensity will be $I = I_0 + I_0 = 2I_0$

Therefore, the desired ratio is

$$\frac{4I_0}{2I_0} = 2$$

Here, I_0 is the intensity due to one slit.

@FAKE_CBSE_X @RAJ_EDUNET

sin table)

[98] For minima $d\sin\theta = n\alpha$

for n to be maximum $\sin\theta = 1$

$n = \frac{6\times10^{-5}}{6\times10^{-7}} = 100$

ce $n = 100$ will corresponds to infinity.

number of minima possible in one is 99 And in both side it is 198

$= I_0\cos^2(\omega t) \Rightarrow I_{av} = \frac{I_0}{2}$

$= \frac{I_0}{2}\times A\times(\Delta t)$

$\frac{\pi}{} = \frac{2\times3.14}{31.4} = \frac{1}{5}$s

$\frac{3.3}{2}\times3\times10^{-4}\times\frac{1}{5} = 1\times10^{-4}$ J

:e unpolarised light falls on nsity of light transmitted from

y of light transmitted form P_2

$^2 30° = \frac{3I_0}{8}$

light transmitted from P_3 is

)°)²

$\frac{1}{} \Rightarrow \frac{I_o}{I} = \frac{32}{3} = 10.67$

ave $\frac{I_1}{I_2} = 4$ but $I \propto A^2$

re (b) and (d).

mid-point intensity will cond case when sources ntensity will be

d ratio is

y due to one slit.

5. [True] At a distance r from a line source of power P and length l, the intensity will be,

$$I = \frac{P}{S} = \frac{P}{2\pi rl} \text{ or } I \propto \frac{1}{r}$$

6. (c) (1) $\Delta x = d\sin\alpha = d\alpha$ (as α is very small)

For $\alpha = \frac{0.36}{180} = (2\times10^{-3})$rad

$$\frac{\Delta x}{\lambda} = \frac{(3\times10^{-4})(2\times10^{-3})}{6\times10^{-7}} = 1$$

$\left[\because \phi = \frac{2\pi}{\lambda}(\Delta x)\right]$

so constructive interference

(2) $\beta = \frac{D\lambda}{d}$

(3) $\Delta x_p = d\alpha + \frac{dy}{D}$

$= 3\times10^{-4}(2\times10^{-3} + 11\times10^{-3})$

$= 39\times10^{-7}$

$\frac{\Delta x_p}{\lambda} = \frac{39\times10^{-7}}{6\times10^{-7}} = 6.5$ so destructive

(4) $\Delta x_p = \frac{dy}{D} = (3\times10^{-4})\times11\times10^{-3}$

$= 33\times10^{-7}$

$\frac{\Delta x_p}{\lambda} = \frac{33\times10^{-7}}{6\times10^{-7}} = 5.5 \Rightarrow$ destructive

7. (c) Path length, $S_2O = \mu\sqrt{x^2+d^2}$

where O is the point of intersection on the water surface.

Path length, $S_1O = \sqrt{x^2+d^2}$

path difference, $\Delta x = S_2O - S_1O$

For constructive interference,

$\Delta x = m\lambda \Rightarrow \sqrt{x^2+d^2}(\mu-1) = m\lambda$

Given, $\mu = \frac{4}{3}$

that gives,

$$x_2 + d_2 = \left(\frac{m\lambda}{\frac{4}{3}-1}\right)^2 \text{ or, } x^2 = 9m^2\lambda^2 - d^2$$

But given, $x^2 = p^2m^2\lambda^2 - d^2$

On comparing we get $p = 3$

8. (b) We have

$$I = 4I_0\cos^2\frac{\phi}{2}\ 2I_0$$

$$= 4I_0\cos^2\frac{\phi}{2} \quad \cos\frac{\phi}{2} = \frac{1}{\sqrt{2}} \quad \phi = \frac{\pi}{2}$$

path difference

$$\Delta x = \frac{\lambda}{2pi}\times\Delta\phi \qquad \Delta x = \frac{\lambda}{4}$$

9. (d) $2d\sin\theta = \lambda$

$$\Rightarrow d = \frac{\lambda}{2\sin\theta}$$

Taking log and differentiating both sides.

$$\frac{\Delta d}{d} = \frac{\Delta\lambda}{\lambda} - \frac{1}{\sin\theta}\cos\theta\Delta\theta$$

For maximum possible error all the errors should be added

$$\Rightarrow \frac{\Delta d}{d} = \frac{\Delta\lambda}{\lambda} + \frac{\cos\theta}{\sin\theta}\Delta\theta$$

As λ is exactly known, $\Delta\lambda = 0$

$$\Rightarrow \frac{\Delta d}{d} = \cot\theta\Delta\theta$$

As $\Delta\theta$, is constant and on increasing θ, $\cot\theta$ decreases.

So, fractional error in $d\left(i.e\ \frac{\Delta d}{d}\right)$ will also decrease.

10. (c) $\varphi = \frac{2\pi}{3} = \frac{2\pi}{\lambda}\Delta x$

where $\Delta x = d\sin\theta$

Substituting in Eq. (i), we get

$$\sin\theta = \frac{\lambda}{3d} \text{ or } \theta = \sin^{-1}\frac{\lambda}{3d}$$

11. (d) Let n^{th} minima of 400nm coincides with m^{th} minima of 560 nm, then

$$(2n-1)\frac{400}{2} = (2m-1)\frac{560}{2}$$

or $\frac{2n-1}{2m-1} = \frac{7}{5} = \frac{14}{10} = \frac{21}{15}$ and so on.

From the first ratio $\frac{7}{5}$, we can see that the 4^{th} minima of 400nm coincides with 3^{rd} minima of 560nm.

Location of this minima is,

$$Y_1 = \frac{(2\times4-1)(1000)(400\times10^{-6})}{2\times0.1}$$

$= 14$ mm

Similarly from the third ratio $\frac{21}{15}$, we can see that the 11^{th} minima of 400 nm will coincide with 8^{th} minima of 560 nm.

Location of this minima is,

$$Y_2 = \frac{(2\times11-1)(1000)(400\times10^{-6})}{2\times0.1}$$

$= 42$ mm

$\therefore$ Required distance $= Y_2 - Y_1 = 28$ mm

12. (b) $PR = d$

$PO = d\sec\theta$

and $CO = PO\cos2\theta = d\sec\theta\cos2\theta$

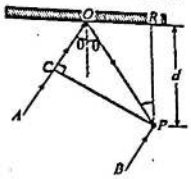
path difference between the two rays is,

$\Delta x = PO + OC$

$= (d\sec\theta + d\sec\theta\cos2\theta)$

phase difference between the two rays is $\Delta\varphi = \pi$(one is reflected, while another is direct)

Therefore, condition for constructive interference should be.



$$\Delta x = \frac{\lambda}{2}, \frac{3\lambda}{2}\ldots$$

or $d\sec\theta(1+\cos2\theta) = \frac{\lambda}{2}$

or $\frac{d}{\cos\theta}(2\cos^2\theta) = \frac{\lambda}{2}$ or $\cos\theta = \frac{\lambda}{4d}$

13. (a) Path difference due to the slab should be an integral multiple of λ or

$\Delta x = n\lambda$ or $(\mu-1)t = n\lambda$ $n = 1, 2, 3, \ldots$

or $t = \frac{n\lambda}{\mu-1}$

For minimum value of t, $n = 1$

$$\therefore t = \frac{\lambda}{\mu-1} = \frac{\lambda}{1.5-1} = 2\lambda$$

14. (b) Fringe width, $\omega = \frac{\lambda D}{d} \propto \lambda$

When the wavelength is decreased from 600 nm to 400 nm, fringe width will also decrease by a factor of $\frac{4}{6}$ or $\frac{2}{3}$ or the number of fringes in the same segment will increase by a factor of 3/2.

Therefore, number of fringes observed in the same segment $= 12\times\frac{3}{2} = 18$

15. (b) $I(\varphi) = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\varphi$

Here, $I_1 = I$ and $I_2 = 4I$

At point $A, \varphi = \frac{\pi}{2}$

$\therefore I_A = I + 4I = 5I$

At point $B, \varphi = \pi$

$\therefore I_B = I + 4I - 4I = I \Rightarrow I_A - I_B = 4I$

16. (a) In interference we know that

$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$

and $I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$

Under normal conditions (when the widths of both the slits are equal)

$I_1 \approx I_2 = I$ (say)

$\therefore I_{max} = 4I$ and $I_{min} = 0$

When the width of one of the slits is increased. Intensity due to that slit

@FAKE_CBSE_X_@RAJEDUNET

would increase, while that of the other will remain same. So, let :

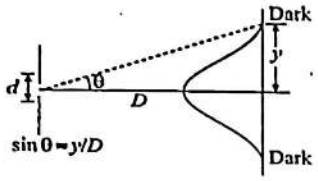
and $I_2 = \eta I$

Then $I_{max} = I(1+\sqrt{\eta})^2 > 4I$

and $I_{min} = I(1+\sqrt{\eta})^2 > 0$

∴ Intensity of both maxima and minima is increased.

17. (*d*) For first dark fringe on either side $d\sin\theta = \lambda$



$$\Rightarrow y = \frac{\lambda D}{d}$$

Therefore, distance between two dark fringes on either side

Substituting the values, we have

$$= 2y = \frac{2\lambda D}{d}$$

$$\text{Distance} = \frac{2(600\times10^{-6}\text{ mm})(2\times10^{3}\text{ mm})}{(1.0\text{ mm})}$$

18. (*c*) $I_{max} = \left(\sqrt{I_1}+\sqrt{I_2}\right)^2 = (\sqrt{4I}+\sqrt{I})^2 = 9I$

$$I_{min} = \left(\sqrt{I_1}-\sqrt{I_2}\right)^2 = (\sqrt{4I}-\sqrt{I})^2 = I$$

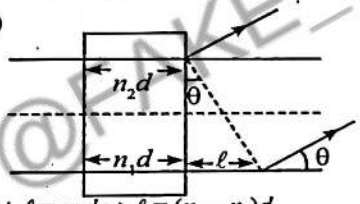
19. (*d*) $\omega = \frac{\lambda D}{d}$.

d is halved and *D* is doubled

Fringe width ω will become four times.

∴ Correct option is (*d*)

20. (*b, d*)



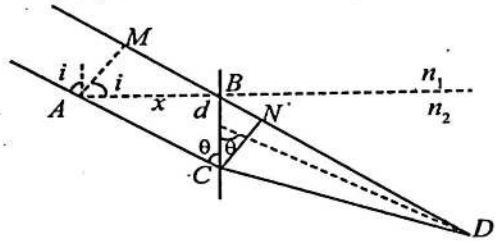
$n_1d + \ell = n_2d \Rightarrow \ell = (n_2 - n_1)d$

Deflection angle; $\tan\theta = \frac{\ell}{h} = \frac{(n_2-n_1)d}{h}$

$\theta = \tan^{-1}\frac{(n_2-n_1)d}{h}$

depends on $(n_2 - n_1)$

21. (*a, b*) Path difference



$\Delta r = (MB + BN) - AC$

$\Delta r = (n_1 x\sin i + n_2 d\cos\theta) - \frac{n_2 d}{\cos\theta}$

$\Delta r = n_1(d\tan\theta)\frac{n_2}{n_1}\sin\theta + n_2 d\cos\theta - \frac{n_2 d}{\cos\theta}$

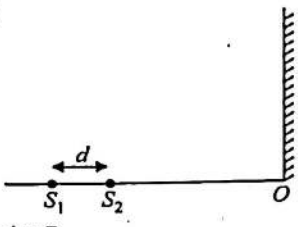
$(\because x = d\tan\theta;\ n_1\sin i = n_2\sin\theta)$

$\Delta r = \frac{n_2 d\sin^2\theta}{\cos\theta} + n_2 d\cos\theta - \frac{n_2 d}{\cos\theta}$

$\Delta r = \frac{n_2 d\left[\sin^2\theta + \cos^2\theta - 1\right]}{\cos\theta} = 0$

$\therefore \Delta\phi = \frac{2\pi}{\lambda}\Delta r = 0$

22. (*a,b*)



At point *D*,

Path difference at point = d = 0.6003 mm = 600300 nm.

So, the path difference = $\left(1000\lambda + \frac{\lambda}{2}\right)$.

⇒ Minima is formed at point *O*.

Here, S_2 and screen are ⊥ to each other

Therefore fringe pattern is circular

23. (*a,b,c*) Here $b = \frac{D\lambda}{d}$

$\because \lambda_2 > \lambda_1 \Rightarrow \beta_2 > \beta_1$

Also $m_1\beta_1 = m_2\beta_2 \Rightarrow m_1 > m_2$

Also $3\left(\frac{D}{d}\right)(600\text{ nm})$

$= (2\times5-1)\left(\frac{D}{2d}\right)400\text{ nm}$

Angular width $\theta = \frac{\lambda}{d}$

24. (*a, b*) Path difference between the lights from S_1 and S_2 reaching the point *P*, $\Delta x = d\sin\theta$

For maxima, $\Delta x = n\lambda$

So, $d\sin\theta = n\lambda$

For $d = \lambda \Rightarrow \sin\theta = n(\sin\theta \equiv 1, -1)$

Thus $n = 0$ gives $\theta = 0$ means there will be only one bright fringe that is central maxima.

Similarly for $\lambda < d < 2\lambda \Rightarrow 1 < \frac{n}{\sin\theta} < 2$

Thus $\sin\theta < n$ and $\sin\theta > \frac{n}{2} \Rightarrow n = 0,1$

Hence there will be one central maxima and first order maxima.

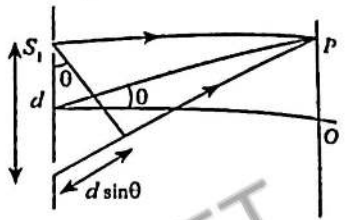
Resultant intensity for dark fringes,

$I = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$

Now initially $I_2 = I_0$ $I_1 = 4I_0$ ⇒ $I = I_0$

When $I_1 = I_2$ gives $I = 0$

Thus by making intensities of both the slits equal, then *I* for dark fringes is always zero i.e, less than the *I* when slits have unequal intensity.



25. (*a,c*) The intensity of light is $I(0) = I_0\cos^2\frac{\delta}{2}$

where, $\delta = \frac{2\pi}{\lambda}(\Delta x) = \frac{2\pi}{\lambda}(d\sin\theta)$

(*a*) For θ = 30° and *d* = 150 m

$\lambda = \frac{c}{\nu} = \frac{3\times10^8}{10^6} = 300\text{ m}$

$\delta = \frac{2\pi}{300}(150)\frac{1}{2} = \frac{\pi}{2}$

$\therefore \frac{\delta}{2} = \frac{\pi}{4}$

$\therefore I(\theta) = I_0\cos^2\frac{\pi}{4} = \frac{I_0}{2}$

[option (*a*)]

(*b*) For θ = 90°

$\delta = \frac{2\pi}{300}(150)(1) = \pi$ or $\frac{\delta}{2} = \frac{\pi}{2}$

and $I(\theta) = 0$

(*c*) For θ = 0°, δ = 0

or $\frac{\delta}{2} = 0$ ∴ $I(\theta) = I_0$

26. (A) → (*p, s*), (B) → (*q*), (C) → (*t*), (D) → (*r,s,t*)

(A) → (*p, s*) → Intensity at P_0 is maximum. It will continuously decrease from P_0 towards P_2

(B) → (*q*) → Path difference due to slap will he compensated by geometrical path difference.

Hence, $\delta(P_1) = 0$.

(C) → (*t*) → $(P_0) = \frac{\lambda}{2}$, $\delta(P_1)$

$= \frac{\lambda}{2} - \frac{\lambda}{4} = \frac{\lambda}{4}$ and $\delta(P_2) = \frac{\lambda}{2} - \frac{\lambda}{3} = \frac{\lambda}{6}$.

When path difference increases from 0 to $\frac{\lambda}{2}$, intensity will decrease from maximum to zero.

Hence, in this case,

@FAKE_CBSE_KA@RAJ_EDUNET

$I(P_3) > I(P_1) > I(P_0)$

$(D) \to (r,s,t)$,

$\delta(P_0) = \frac{3\lambda}{4}$, $\delta(P_1) = \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2}$

and $\delta(P_2) = \frac{3\lambda}{4} - \frac{\lambda}{3} = \frac{5\lambda}{12}$.

In this case $I(P_1) = 0$.

27. [3.5] Let n_1 bright fringe corresponding to wavelength $\lambda_1 = 500$ nm coincides with n_2 bright fringe corresponding to wavelength $\lambda_2 = 700$.

$\therefore n_1\frac{\lambda_1 D}{d} = n_2\frac{\lambda_2 D}{d}$

or $\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} = \frac{7}{5}$

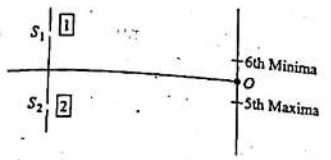
This implies that 7^{th} maxima of λ_1 coincides with 5^{th} maxima of λ_2. Similarly 14^{th} maxima of λ_1 will coincide with 10th maxima of λ_2 and so on.

$\therefore$ Minimum distance $= \frac{n_1\lambda_1 D}{d}$

$= 7 \times 5 \times 10^{-7} \times 10^3 = 3.5 \times 10^{-3} = 3.5$ mm

28. [9.3] $\mu_1 = 1.4$ and $\mu_2 = 1.7$ and let t be the thickness of each glass plates.

Path difference at O, due to insertion of glass plates will be



$\Delta x = (\mu_1 - \mu_2)t = (1.7 - 1.4)t = 0.3t$

Now, since 5^{th} maxima (earlier) lies below O and 6^{th} minima lies above O.

This path difference should lie between 5λ and $5\lambda + \frac{\lambda}{2}$

So, let $\Delta x = 5\lambda + \Delta$

where $\Delta < \frac{\lambda}{2}$

Due to the path difference Δx, the phase difference at O will be

$\varphi = \frac{2\pi}{\lambda}\Delta x = \frac{2\pi}{\lambda}(5\lambda + \Delta)$ ...(i)

$= \left(10\pi + \frac{2\pi}{\lambda}\cdot\Delta\right)$

Intensity at O is given $\frac{3}{4}I_{max}$ and since

$I(\varphi) = I_{max}\cos^2\frac{\varphi}{2}$

$\therefore \frac{3}{4}I_{max} = I_{max}\cos^2\frac{\varphi}{2}$ or $\frac{3}{4} = \cos^2\frac{\varphi}{2}$ ...(ii)

From Eqs. (i) and (ii), we find that

$\Delta = \frac{\lambda}{6}$

i.e., $\Delta x = 5\lambda + \frac{\lambda}{6} = \frac{31}{6}\lambda = 0.3t$

$\therefore t = \frac{31\lambda}{6(0.3)} = \frac{(31)(5400\times10^{-10})}{1.8}$

or $t = 9.3 \times 10^{-4} = 9.3\mu$m

29. [7×10⁻⁶] Power received by aperture A,

$P_A = I(\pi r_A^2) = \frac{10}{\pi}(\pi)(0.001)^2 = 10^{-5}$ W

Power received by aperture B,

$P_B = I(\pi r_B^2) = \frac{10}{\pi}(\pi)(0.002)^2 = 4\times10^{-5}$W

Only 10% of P_A and P_B goes to the original direction. Hence, 10% of $P_A = 10^{-6} = P_{1(say)}$ and 10% of $P_B = 4 \times 10^{-6} = P_2$(say)

Path difference created by slab

$\Delta x = (\mu - 1)t$

$= (1.5 - 1)(2000) = 1000$Å

Corresponding phase difference,

$\varphi = \frac{2\pi}{\lambda}\cdot\Delta x = \frac{2\pi}{6000}\times1000 = \frac{\pi}{3}$

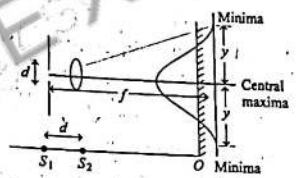
Now, resultant power at the focal point

$P = P_1 + P_2 + 2\sqrt{P_1P_2}\cos\varphi$

$= 10^{-6} + 4\times10^{-6} + 2\sqrt{(10^{-6})(4\times10^{-6})}\cos\frac{\pi}{3}$

$= 7 \times 10^{-6}$ W

30. Given



$2y = 2\times10^{-3}$ m $\Rightarrow y = 1\times10^{-3}$ m

First minima is obtained at

$d\sin\theta = \lambda$ but $\sin\theta \approx \tan\theta = \frac{y}{f}$

$\therefore d\frac{y}{f} = \lambda$

$d = \frac{\lambda f}{y} = \frac{5.89\times10^{-7}\times0.5}{1\times10^{-3}} = 2.945\times10^{-4}$m

31. [True] To obtain interference, sources must be coherent. Two different light sources can never be coherent.

32. [False] With white light we get coloured fringes (not only black and white) with centre as white.

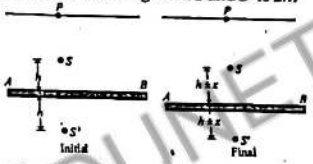
33. (*a*) Shape of the interference fringes will be circular.

(*b*) Intensity of light reaching on the screen directly from the source $I_1 = I_0$ (say) and intensity of light reaching on the screen after reflecting from the mirror is $I_2 = 36\%$ of $I_0 = 0.36\,I_0$

$\therefore \frac{I_1}{I_2} = \frac{I_0}{0.36I_0} = \frac{1}{0.36}$ or $\sqrt{\frac{I_1}{I_2}} = \frac{1}{0.6}$

$\therefore \frac{I_{min}}{I_{max}} = \frac{\left(\sqrt{\frac{I_1}{I_2}}-1\right)^2}{\left(\sqrt{\frac{I_1}{I_2}}+1\right)^2} = \frac{\left(\frac{1}{0.6}-1\right)^2}{\left(\frac{1}{0.6}+1\right)^2} = \frac{1}{16}$

(*c*) Initially path difference at P between two waves reaching from S and S' is $2h$.



Therefore, for maximum intensity at P: $2h = \left(n - \frac{1}{2}\right)\lambda$ ...(i)

Now, let the reflecting surface AB is displaced by x Then new path difference will be $2h + 2x$ or $2h - 2x$. So, again for maximum intensity at P.

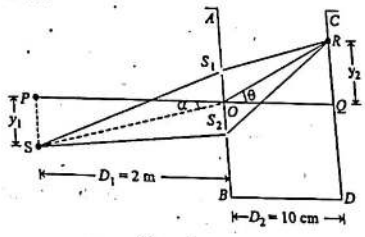
$2h + 2x = \left(n + 1 - \frac{1}{2}\right)\lambda$ ...(ii)

or $2h - 2x = \left(n - 1 - \frac{1}{2}\right)\lambda$ ...(iii)

Solving Eqs. (i) and (ii) or Eqs. (i) and (iii), we get

$x = \frac{\lambda}{2} = \frac{600}{2} = 300$ nm

34. Given $y_1 = 40$ cm, $D_1 = 2$ m $= 200$ cm, $D_2 = 10$ cm



$\tan\alpha = \frac{y_1}{D_1} = \frac{40}{200} = \frac{1}{5}$

$\Rightarrow \alpha = \tan^{-1}(1/5)$

$\sin\alpha = \frac{1}{\sqrt{26}} \approx \frac{1}{5} = \tan\alpha$

Path difference between SS_1 and SS_2 is

$\Delta X_1 = SS_1 - SS_2$ or $\Delta X_1 = d\sin\alpha = (0.8\text{mm})\frac{1}{5}$

or $\Delta X_1 = 0.16$ mm

@FAKE_CBSE_X @RAJ_EDUNET

Now, let at point R on the screen, central bright fringe is observed (i.e., net path difference = 0).

Path difference between S_2R and S_1R would be

$\Delta X_2 = S_2R - S_1R$

$DX_2 = d\sin\theta$

Central bright fringe is observed where net path difference is zero.

or $\Delta X_2 - \Delta X_1 = 0$

$\Delta X_2 = \Delta X_1$

or $d\sin\theta = 0.16$

or $(0.8)\sin\theta = 0.16$

or $\sin\theta = \dfrac{0.16}{0.8} = \dfrac{1}{5}$

$$\tan\theta = \frac{1}{\sqrt{24}} = \sin\theta = \frac{1}{5}$$

Hence, $\tan\theta = \dfrac{y_2}{D_2} = \dfrac{1}{5}$

$$\therefore \quad y_2 = \frac{D_2}{5} = \frac{10}{5} = 2\,\text{cm}$$

Therefore, central bright fringe is observed at 2 cm above point Q on side CD.

35. Given, $\lambda = 600\ \text{nm} = 6\times10^{-7}\,\text{m}$,

$d = 0.45\ \text{nm} = 0.45\times10^{-3}\,\text{m}$

$D = 1.5\ \text{m}$

Thickness of glass sheet,

$t = 10.4\ \mu\text{m} = 10.4\times10^{-6}\,\text{m}$

Refractive index of medium, $\mu_m = 4/3$

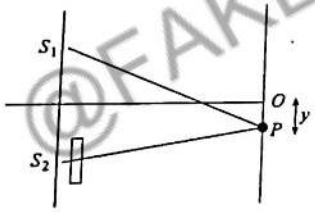
and refractive index of glass sheet, $\mu_g = 1.5$

(*a*) Let central maximum is obtained at a distance y below point O. Then

$$\Delta x_1 = S_1P - S_2P = \frac{yd}{D}$$

Path difference due to glass sheet

$$\Delta x_2 = \left(\frac{\mu_g}{\mu_m} - 1\right)t$$



Net path difference will be zero when

$$\Delta x_1 = \Delta x_2 \text{ or } \frac{yd}{D} = \left(\frac{\mu_g}{\mu_m} - 1\right)t$$

$$\therefore y = \left(\frac{\mu_g}{\mu_m} - 1\right)\frac{tD}{d}$$

Substituting the values, we have

$$y = \left(\frac{1.5}{4/3} - 1\right)\frac{10.4\times10^{-6}(1.5)}{0.45\times10^{-3}}$$

$y = 4.33\times10^{-3}\,\text{m}$

or we can say $y = 4.33$ mm .

(*b*) At O, $\Delta x_1 = 0$ and $\Delta x_2 = \left(\dfrac{\mu_g}{\mu_m} - 1\right)t$

$\therefore$ Net path difference, $\Delta x = \Delta x_2$

Corresponding phase difference, $\Delta\varphi$ or φ

or $\varphi = \dfrac{2\pi}{\lambda}\cdot\Delta x$

Substituting the values, we have

$$\varphi = \frac{2\pi}{6\times10^{-7}}\left(\frac{1.5}{4/3} - 1\right)(10.4\times10^{-6})$$

$$\varphi = \frac{13}{3}\pi$$

Now $I(\varphi) = I_{max}\cos^2\dfrac{\varphi}{2}$

$$\therefore I = I_{max}\cos^2\left(\frac{13\pi}{6}\right)$$

$$I = \frac{3}{4}I_{max}$$

(*c*) At O, path difference is

$$\Delta x = \Delta x_2 = \left(\frac{\mu_g}{\mu_m} - 1\right)t$$

For maximum intensity at O

$\Delta x = n\lambda$

$$\therefore \lambda = \frac{\Delta x}{1}, \frac{\Delta x}{2}, \frac{\Delta x}{3} \ldots \text{ and so on}$$

$$\Delta x = \frac{1.5}{4/3} - 1(10.4\times10^{-6}\ \text{m})$$

$$= \frac{1.5}{4/3} - 1(10.4\times10^{3}\ \text{nm})$$

$\Delta x = 1300$ nm

$\therefore$ Maximum intensity will be corresponding to

$\lambda = 1300\ \text{nm}, \dfrac{1300}{2}\ \text{nm}, \dfrac{1300}{3}\ \text{nm}, \dfrac{1300}{4}\ \text{nm} \ldots$

$= 1300\ \text{nm}, 650\ \text{nm}, 433.33\ \text{nm}, 325\ \text{nm} \ldots$

The wavelengths in the range 400 to 700 nm are 650 nm and 433.33 nm.

36. Given, $\lambda = 0.5$ mm, $d = 1.0$ mm, $D = 1$m

(*a*) When the incident beam falls normally:

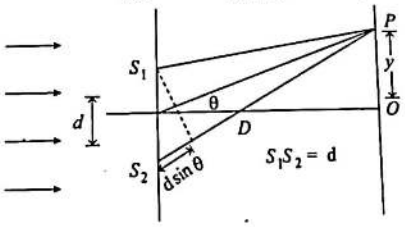
Path difference between the two rays S_2P and S_1P is

$\Delta x = S_2P - S_1P \approx d\sin\theta$

For minimum intensity,

$$d\sin\theta = (2n-1)\frac{\lambda}{2} \text{ where } n = 1, 2, 3, \ldots$$

$$\text{or } \sin\theta \ \frac{(2n-1)\lambda}{2d} = \frac{(2n-1)\lambda}{2\times1.0} = \frac{2n-1}{4}$$



As $\sin\theta \le 1$ therefore $\dfrac{(2n-1)}{4} \le 1$

or $n \le 2.5$

So, n can be either 1 or 2 .

when $n = 1, \sin\theta_1 = \dfrac{1}{4}$ or $\tan\theta_1 = \dfrac{1}{\sqrt{15}}$

$n = 2, \sin\theta_2 = \dfrac{3}{4}$ or $\tan\theta_2 = \dfrac{3}{\sqrt{7}}$

$\therefore\ y = D\tan\theta = \tan\theta \qquad (D = 1\ \text{m})$

So, the position of minima will be

$y_1 = \tan\theta_1 = \dfrac{1}{\sqrt{15}}\ \text{m} = 0.26\ \text{m}$

$y_2 = \tan\theta_2 = \dfrac{3}{\sqrt{7}}\ \text{m} = 1.13\ \text{m}$

And as minima can be on either side of centre O.

Therefore there will be four minima at positions ±0.26 m and ±1.13 m on the screen.

(*b*) When $\alpha = 30°$, path difference between the rays before reaching S_1 and S_2 is

$\Delta x_1 = d\sin\alpha = (1.0)\sin30° = 0.5\ \text{mm} = \lambda$

So, there is already a path difference of λ between the rays.

Position of central maximum Central maximum is defined as a point where net path difference is zero. So,

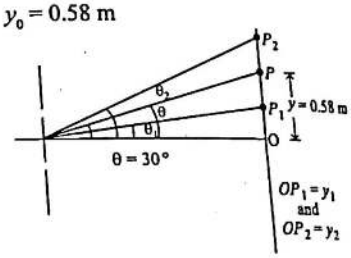
$\Delta x_1 = \Delta x_1$

or $d\sin\alpha = d\sin\theta$ or $\theta = \alpha = 30°$

$$\tan\theta = \frac{1}{\sqrt{3}} = \frac{y_0}{D}$$

$$y_0 = \frac{1}{\sqrt{3}}\ \text{m}$$

$y_0 = 0.58$ m



At point P,

$\Delta x_1 = \Delta x_2$

Above point P $\Delta x_2 > \Delta x_1$ and

Below point P $\Delta x_1 > \Delta x_2$

Now, let P_1 and P_2 be the minima on either side of central maxima. Then, for P_2

$$\Delta x_2 - \Delta x_1 = \frac{\lambda}{2}$$

$$\text{or } \Delta x_2 = \Delta x_1 + \frac{\lambda}{2} = \lambda + \frac{\lambda}{2} = \frac{3\lambda}{2}$$

$$\text{or } d\sin^2\theta = \frac{3\lambda}{2}$$

@FAKE_CBSE_K @RAJ_PHYSICS

$\text{or } \sin\theta_2 = \frac{3\lambda}{2d} = \frac{(3)(0.5)}{(2)(1.0)} = \frac{3}{4}$

$\therefore \tan\theta_2 = \frac{3}{\sqrt{7}} = \frac{y_2}{D}$

$\text{or } y^2 = \frac{3}{\sqrt{7}} = 1.13 \text{ m}$

Similarly by for P_1

$\Delta x_1 - \Delta x_2 = \frac{\lambda}{2}$ or $\Delta x_2 = \Delta x_1 - \frac{\lambda}{2}$

$= \lambda - \frac{\lambda}{2} = \frac{\lambda}{2}$ or $d\sin\theta_1 = \frac{\lambda}{2}$

$\text{or } \sin\theta_1 = \frac{\lambda}{2d} = \frac{(0.5)}{(2)(1.0)} = \frac{1}{4}$

$\therefore \tan\theta_1 = \frac{1}{\sqrt{15}} = \frac{y_1}{D}$

$\text{or } y_1 = \frac{1}{\sqrt{15}} \text{ m} = 0.26 \text{ m}$

Therefore, y-coordinates of the first minima on either side of the central maximum are $y_1 = 0.26$ m and $y_2 = 1.13$ m.

NOTE: In this problem $\sin\theta \approx \tan\theta \approx \theta$ is not valid as θ is large.

37. (*a*) Path difference due to the glass slab,
$\Delta x = (\mu - 1)t = (1.5 - 1)t = 0.5t$
Due to this slab, 5 red fringes have been shifted upwards.
Therefore, $\Delta x = 5\lambda_{red}$
or $0.5t = (5)(7 \times 10^{-7} \text{ m})$
$\therefore$ t = thickness of glass slab $= 7 \times 10^{-6}$ m

(*b*) Let μ' be the refractive index for green light then
$\Delta x' = (\mu' - 1)t$
Now the shifting is of 6 fringes of red light. Therefore,
$\Delta x' = 6\lambda_{red}$
$\therefore (\mu' - 1)t = 6\lambda_{red}$
$\therefore (\mu' - 1) = \frac{(6)(7\times10^{-7})}{7\times10^{-6}} = 0.6$
$\therefore \mu' = 1.6$

(*c*) In part (*a*), shifting of 5 bright fringes was equal to 10^{-3} m. Which implies that
$5\omega_{red} = 10^{-3}$ m
(Here, ω = Fringe width)
$\therefore \omega_{red} = \frac{10^{-3}}{5} \text{ m} = 0.2 \times 10^{-3}$ m

Now since $\omega = \frac{\lambda D}{d}$

or $\omega \propto \lambda$

$\therefore \frac{\omega_{green}}{\omega_{red}} = \frac{\lambda_{green}}{\lambda_{red}}$

$\therefore \omega_{green} = \omega_{red}\frac{\lambda_{green}}{\lambda_{red}}$

$= (0.2 \times 10^{-3})\left(\frac{5\times10^{-7}}{7\times10^{-7}}\right)$

$\omega_{green} = 0.143 \times 10^{-3}$ m

$\therefore \Delta\omega = \omega_{green} - \omega_{red}$
$= (0.143 - 0.2) \times 10^{-3}$ m
$\Delta\omega = -5.71 \times 10^{-5}$ m

38. Given, $\mu = 1.33$, $d = 1$mm, $D = 1.33$ m, $\lambda = 6300$ Å

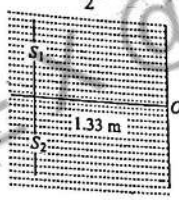
(*a*) Wavelength of light in the given liquid :
$\lambda' = \frac{\lambda}{\mu} = \frac{6300}{1.33}$ Å ≈ 4737 Å
$= 4737 \times 10^{-10}$ m
$\therefore$ Fringe width,
$\omega = \frac{(4737\times10^{-10} \text{ m})(1.33 \text{ m})}{(1\times10^{-3} \text{ m})}$
$= 6.3 \times 10^{-4}$
$\omega = 0.63$ mm

(*b*) Let t be the thickness of the glass slab. Path difference due to glass slab at centre O.

$\Delta x = \frac{\mu_{glass}}{\mu_{liquid}} - 1t = \frac{1.53}{1.33} - 1t$

or $\Delta x = 0.15t$

Now, for the intensity to be minimum at O, this path difference should be equal to $\frac{\lambda'}{2}$



$\therefore \Delta x = \frac{\lambda'}{2}$ or $0.15t = \frac{4737}{2}$ Å

$\therefore t = 1.5790$ Å or $t = 1.579\mu$m

39. (*a*) For the lens, $= u = -0.15$ m ; $f = +0.10$ m

Therefore, using $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ we have

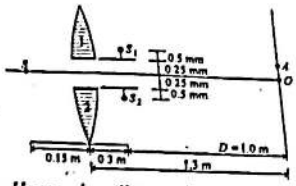
$\frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{(-0.15)} + \frac{1}{(0.10)}$

or $v = 0.3$m

Linear magnification,

$m = \frac{v}{u} = \frac{0.3}{-0.15} = -2$

Hence, two images S_1 and S_2 of S will be formed at 0.3 m from the lens as shown in figure. Image S_1 due to part 1 will be formed at 0.5 mm above its optic axis ($m = -2$). Similarly, S_2 due to part 2 is formed 0.5 mm below the optic axis of this part as shown.



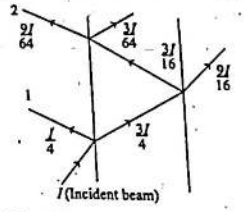
Hence, d = distance between S_1 and S_2 = 1.5 mm
D = 1.30 − 0.30 = 1.0 m = 10^3 mm
l = 500 nm = 5×10^{-4} mm
Therefore, fringe width,
$\omega = \frac{\lambda D}{d} = \frac{(5\times10^{-4})(10^3)}{(1.5)} = \frac{1}{3}$ mm

Now, as the point A is at the third maxima
$OA = 3\omega = 3(1/3)$mm or $OA = 1$ mm

NOTE: The language of the question is slightly confusing. The third intensity maximum may be understood as second order maximum (zero order, first order and the second order). In that case $OA = 2\omega = 2(1/3)$ mm = 0.67 mm.

(*b*) If the gap between L_1 and L_2 is reduced, d will decrease. Hence, the fringe width ω will increase or the distance OA will increase.

40. Each plate reflects 25% and transmits 75%.



Incident beam has an intensity I. This beam undergoes multiple reflections and refractions. The corresponding intensity after each reflection and refraction (transmission) are shown in figure.

Interference pattern is to take place between rays 1 and 2.

$I_1 = \frac{I}{4}$ and $I_2 = \frac{9I}{64}$

$\frac{I_{min}}{I_{max}} = \frac{\sqrt{I_1} - \sqrt{I_2}^2}{\sqrt{I_1} + \sqrt{I_2}} = \frac{1}{49}$

41. (*a*) The desired distance will be
$y_1 = 3\omega_1$
$= 3\frac{\lambda_1 D}{d} = \frac{(3)(6500\times10^{-10})(1.2)}{(2\times10^{-3})}$
$= 11.7 \times 10^{-4}$ m = 1.17 mm

@FAKE_CBSE_@RAJ_FREE_NET

(*b*) Let n_1 bright fringe of λ_1 coincides with n_2 bright fringe of λ_2. Then,

$$\frac{n_1\lambda_1 D}{d}=\frac{n_2\lambda_2 D}{d} \text{ or } \frac{n_1}{n_2}=\frac{\lambda_2}{\lambda_1}=\frac{5200}{6500}=\frac{4}{5}$$

Therefore, 4th bright of λ_1 coincides with 5th bright of λ_2. Similarly, 8th bright of λ_1 will coincide with 10th bright of λ_2 and so on. The least distance from the central maximum will therefore corresponding to 4th bright of λ_1 (or 5 th bright of λ_2 .) Hence,

$$Y_{min}=\frac{4\lambda_1 D}{d}=\frac{4\left(6500\times10^{-10}\right)(1.2)}{\left(2\times10^{-3}\right)}$$

$15.6\times10^{-4}\,\text{m}=1.56\,\text{m}$

42. Shifting of fringes due to introduction of slab in the path of one of the slits, comes out to be,

$$\Delta y=\frac{(\mu-1)tD}{d}$$

Now, the distance between the screen and slits is doubled.

Hence, the new fringe width will become.

$$\omega'=\frac{\lambda(2D)}{d}$$

Given, $\Delta y=\omega'$ or $\frac{(\mu-1)tD}{d}=\frac{2\lambda D}{d}$

$$\therefore\ \lambda=\frac{(\mu-1)t}{2}=\frac{(1.6-1)\left(1.964\times10^{-6}\right)}{2}$$

$=0.5892\times10^{-6}\,\text{m}=5892\text{Å}$

43. (*c,d*) $\lambda=600$ nm at $P_1\Delta x=1$

$P_2\Delta x=1.8\text{ mm}=n\lambda$

Hence, bright fringe will be formed.

At P_2, 3000th maxima is formed.

For (*a*) option

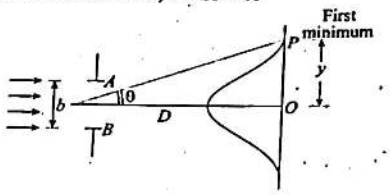
$\Delta x=d\sin\theta\Rightarrow d\Delta x=d\cos d\theta$

$$R\lambda=d\cos\theta Rd\theta\Rightarrow Rd\theta=\frac{R\lambda}{docs\theta}$$

If moved from P_1 to P_2

$\theta\uparrow\ \cos\theta\downarrow\ Rd\theta\uparrow$

44. At first minima, $b\sin\theta=\lambda$



or $b\theta=\lambda$ or $b\frac{y}{D}=\lambda$ or $y=\frac{\lambda D}{b}$

or $\frac{yb}{D}=\lambda$

Now, at P (First minima) path difference between the rays reaching from two edges (A and B) will be

$\Delta x=\frac{yb}{D}$ (compare b with Δx in *YDSE*)

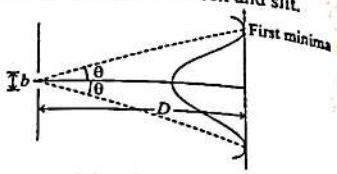
or $\Delta x=\lambda$ From Eq. (*i*)

Corresponding phase difference (φ) will be

$$\varphi=\frac{2\pi}{\lambda}\cdot\Delta x,\varphi=\frac{2\pi}{\lambda}\cdot\lambda=2\pi$$

45. (*a*) Given, $\lambda=6000$Å

Let b be the width of slit and D the distance between screen and slit.



First minima is obtained at $b\sin\theta=\lambda$ or $b\theta=\lambda$ as $\sin\theta\approx\theta$

or $\theta=\frac{\lambda}{b}$

Angular width of first maxima

$=2\theta=\frac{2\lambda}{b}\propto\lambda$

Angular width will decrease by 30% when λ is also decreased by 30%.

Therefore, new wavelength

$$\lambda'=(6000)-\left(\frac{30}{100}\right)6000$$

$\lambda'=4200$Å

(*b*) When the apparatus is immersed in a liquid of refractive index μ, the wavelength is decreased μ times. Therefore,

$$4200\text{Å}=\frac{6000\text{Å}}{\mu}$$

$\therefore\ \mu=\frac{6000}{4200}$ or $\mu=1.429\simeq1.43$

@FAKE_CBSE X @RAJ_EDUNET

27

Dual Nature of Radiation and Matter

Scan for Sol.

JEE-Main

Photon Theory of Light & Radiation Pressure

1. If the total energy transferred to a surface in time t is 6.48×10^5 J, then the magnitude of the total momentum delivered to this surface for complete absorption will be: **[30 Jan, 2024 (Shift-II)]**
   (a) 2.46×10^{-3} kg m/s (b) 2.16×10^{-3} kg m/s
   (c) 1.58×10^{-3} kg m/s (d) 4.32×10^{-3} kg m/s

2. An object is placed in a medium of refractive index 3. An electromagnetic wave of intensity 6×10^8 W/m^2 falls normally on the object and it is absorbed completely. The radiation pressure on the object would be (speed of light in free space $= 3 \times 10^8$ m/s): **[27 JAN, 2024 (Shift-II)]**
   (a) 36 Nm^{-2} (b) 18 Nm^{-2} (c) 6 Nm^{-2} (d) 2 Nm^{-2}

3. Two sources of light emit with a power of 200 W. The ratio of number of photons of visible light emitted by each source having wavelengths 300 nm and 500 nm respectively, will be: **[29 Jan, 2024 (Shift-II)]**
   (a) 1 : 5 (b) 1 : 3 (c) 5 : 3 (d) 3 : 5

4. Monochromatic light of frequency 6×10^{14} Hz is produced by a laser. The power emitted is 2×10^{-3} W. How many photons per second on an average, are emitted by the source?
   (Given $h = 6.63 \times 10^{-34}$ Js) **[1 Feb, 2024 (Shift-II)]**
   (a) 9×10^{18} (b) 6×10^{15} (c) 5×10^{15} (d) 7×10^{16}

5. The number of electrons flowing per second in the filament of a 110 W bulb operating at 220 V is:
   (Given e $= 1.6 \times 10^{-19}$ C) **[06 April, 2024 (Shift-II)]**
   (a) 31.25×10^{17} (b) 6.25×10^{18}
   (c) 6.25×10^{17} (d) 1.25×10^{19}

6. If a source of electromagnetic radiation having power $15kW$ produces 10^{16} photons per second, the radiation belongs to a part of spectrum is.
   (Take Planck constant $h = 6 \times 10^{-34}$ Js) **[31 Jan, 2023 (Shift-I)]**
   (a) Micro waves (b) Ultraviolet rays
   (c) Gamma rays (d) Radio waves

7. Given below are two statements:
   Statements-I: Two photons having equal linear momenta have equal wavelengths
   Statements-II: If the wavelength of photon is decreased, then the momentum and energy of a photon will also decrease.
   In the light of the above statements, choose the correct answer from the options given below. **[24 Feb, 2021 (Shift-I)]**
   (a) Both Statement-I and Statement-II are false
   (b) Statement-I is false but Statement-II is true
   (c) Both statement-I and Statement-II are true
   (d) Statement-I is true but statement-II is false.

8. The wavelength of an X-ray beam is 10Å. The mass of a fictitious particle having the same energy as that of the X-ray photons is $\frac{x}{3}$ h kg. The value of x is_____.
   (h = Planck's constant) **[25 Feb, 2021 (Shift-II)]**

9. Two sources of light emit X-rays of wavelength 1 nm and visible light of wavelength 500 nm, respectively. Both the sources emit light of the same power 200 W. The ratio of the number density of photons of X-rays to the number density of photons of the visible light of the given wavelengths is: **[3 Sep, 2020 (Shift-II)]**
   (a) $\frac{1}{500}$ (b) 500 (c) 250 (d) $\frac{1}{250}$

10. A 2 mW laser operates at a wavelength of 500 nm. The number of photons that will be emitted per second is
    [Given Planck's constant $h = 6.6 \times 10^{-34}$ Js,] **[10 April, 2019 (Shift-II)]**
    (a) 2×10^{16} (b) 1.5×10^{16} (c) 5×10^{15} (d) 1×10^{16}

Photoelectric Effect

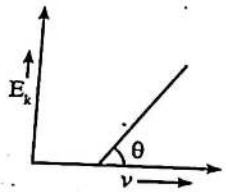
11. When a metal surface is illuminated by light of wavelength λ, the stopping potential is 8V. When the same surface is illuminated by light of wavelength 3λ, stopping potential is 2V. The threshold wavelength for this surface is: **[31 Jan, 2024 (Shift-I)]**
    (a) 5λ (b) 3λ (c) 9λ (d) 4.5λ

12. In a photoelectric effect experiment a light of frequency 1.5 times the threshold frequency is made to fall on the surface of photosensitive material. Now if the frequency is halved and intensity is doubled, the number of photo electrons emitted will be: **[31 Jan, 2024 (Shift-II)]**
    (a) Doubled (b) Quadrupled
    (c) Zero (d) Halved

13. The work function of a substance is 3.0 eV. The longest wavelength of light that can cause the emission of photoelectrons from this substance is approximately: **[30 Jan, 2024 (Shift-I)]**
    (a) 215 nm (b) 414 nm (c) 400 nm (d) 200 nm

©TARGET JEE EXCEL EDUNET

14. For the photoelectric effect, the maximum kinetic energy (E_k) of the photoelectrons is plotted against the frequency (ν) of the incident photons as shown in figure. The slope of the graph gives
[30 Jan, 2024 (Shift-II)]



(a) Ratio of Planck's constant to electric charge
(b) Work function of the metal
(c) Charge of electron
(d) Planck's constant

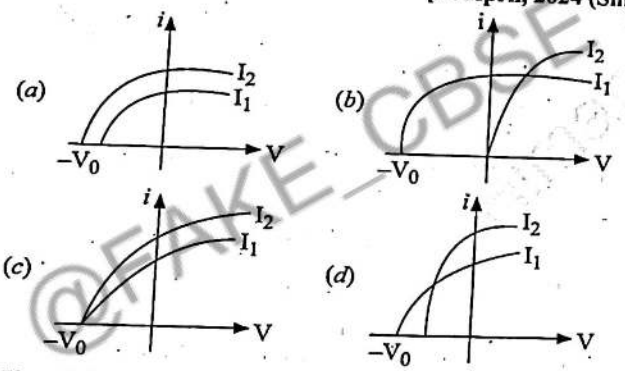
15. A convex lens of focal length 40 cm forms an image of an extended source of light on a photoelectric cell. A current I is produced. The lens is replaced by another convex lens having the same diameter but focal length 20 cm. The photoelectric current now is:
[27 Jan, 2024 (Shift-I)]

(a) $\frac{I}{2}$ (b) $4I$ (c) $2I$ (d) I

16. The threshold frequency of a metal with work function 6.63eV is:
[27 JAN, 2024 (Shift-II)]

(a) 16×10^{15} Hz (b) 16×10^{12} Hz
(c) 1.6×10^{12} Hz (d) 1.6×10^{15} Hz

17. Which figure shows the correct variation of applied potential difference (V) with photoelectric current (I) at two different intensities of light ($I_1 < I_2$) of same wavelengths:
[04 April, 2024 (Shift-I)]



18. Given below are two statements: One is labelled as **Assertion A** and the other is labelled as **Reason R.**

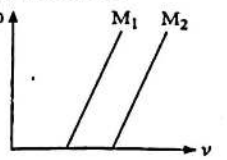
Assertion A: Number of photons increases with increase in frequency of light.

Reason R: Maximum kinetic energy of emitted electrons increases with the frequency of incident radiation.

In the light of the above statements, choose the most appropriate answer from the options given below:
[04 April, 2024 (Shift-II)]

(a) Both A and R are correct and R is NOT the correct explanation of A.
(b) A is correct but R is not correct.
(c) Both A and R are correct and R is the correct explanation of A.
(d) A is not correct but R is correct.

19. Given below are two statements:



Statement-I: Figure shows the variation of stopping potential with frequency (ν) for the two photosensitive materials M_1 and M_2. The slope gives value of h/e, where h is Planck's constant, e is the charge of electron.

Statement-II: M_2 will emit photoelectrons of greater kinetic energy for the incident radiation having same frequency.

In the light of the above statements, choose the most appropriate answer from the options given below.
[05 April, 2024 (Shift-I)]

(a) **Statement-I** is correct and **Statement-II** is incorrect.
(b) **Statement-I** is incorrect but **Statement-II** is correct.
(c) Both **Statement-I** and **Statement-II** are incorrect.
(d) Both **Statement-I** and **Statement-II** are correct.

20. Which of the following statement is not true about stopping potential (V_0)?
[05 April, 2024 (Shift-II)]

(a) It depends on the nature of emitter material.
(b) It depends upon frequency of the incident light.
(c) It increases with increase in intensity of the incident light.
(d) It is $1/e$ times the maximum kinetic energy of electrons emitted.

21. In photoelectric experiment energy of 2.48 eV irradiates a photo sensitive material. The stopping potential was measured to be 0.5 V. Work function of the photo sensitive material is:
[06 April, 2024 (Shift-I)]

(a) 0.5 eV (b) 1.68 eV (c) 2.48 eV (d) 1.98 eV

22. When UV light of wavelength 300 nm is incident on the metal surface having work function 2.13 eV, electron emission takes place. The stopping potential is : (Given $hc = 1240$ eV nm)
[06 April, 2024 (Shift-II)]

(a) 4 V (b) 4.1 V (c) 2 V (d) 1.5 V

23. UV light of 4.13 eV is incident on a photosensitive metal surface having work function 3.13 eV. The maximum kinetic energy of ejected photoelectrons will be:
[09 April, 2024 (Shift-II)]

(a) 4.13 eV (b) 1 eV (c) 3.13 eV (d) 7.26 eV

24. From the photoelectric effect experiment, following observations are made. Identify which of these are correct

A. The stopping potential depends only on the work function of the metal.
B. The saturation current increases as the intensity of incident light increases.
C. The maximum kinetic energy of a photo electron depends on the intensity of the incident light.
D. Photoelectric effect can be explained using wave theory of light.

Choose the correct answer from the options given below:
[24 Jan, 2023 (Shift-I)]

(a) B, C only (b) A, C, D only
(c) B only (d) A, B, D only

25. The work functions of Aluminium and Gold are 4.1 eV and 5.1 eV respectively. The ratio of the slope of the stopping potential versus frequency plot for Gold to that of Aluminium is
[6 April, 2023 (Shift-II)]

(a) 1.24 (b) 2 (c) 1 (d) 1.5

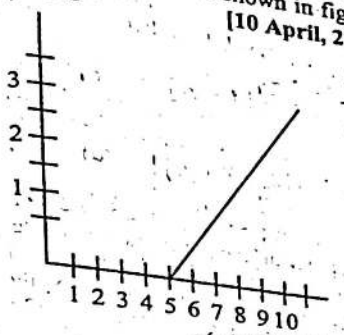
@FAKE_CBSE_X@RM_EDUNET

26. The difference between threshold wavelengths for two metal surfaces A and B having work function $\phi_A = 9$ eV and $\phi_B = 4.5$ eV in nm is
(Given, hc = 1242 eV nm)
(a) 264 (b) 138 (c) 276 (d) 540
[13 April, 2023 (Shift-I)]

27. If the two metals A and B are exposed to radiation of wavelength 350 nm. The work functions of metals A and B are 4.8 eV and 2.2 eV. Then choose the correct option
[31 Jan, 2023 (Shift-II)]
(a) Metal B will not emit photo-electrons
(b) Both metals A and B will emit photo-electrons
(c) Both metals A and B will not emit photoelectrons
(d) Metal A will not emit photo-electrons

28. A metallic surface is illuminated with radiation of wavelength λ, the stopping potential is V_0. If the same surface is illuminated with radiation of wavelength 2λ, the stopping potential becomes $\frac{V_0}{4}$. The threshold wavelength for this metallic surface will be -
[11 April, 2023 (Shift-I)]
(a) $\frac{\lambda}{4}$ (b) 4λ (c) $\frac{3}{2}\lambda$ (d) 3λ

29. The variation of stopping potential (V_0) as a function of the frequency (ν) of the incident light for a metal is shown in figure. The work function of the surface is
[10 April, 2023 (Shift-II)]



(a) 18.6 eV (b) 2.98 eV (c) 2.07 eV (d) 1.36 eV

30. Given below are two statements:
Statement-I: Out of microwaves, infrared rays and ultraviolet rays, ultraviolet rays are the most effective for the emission of electrons from a metallic surface.
Statement-II: Above the threshold frequency, the maximum kinetic energy of photoelectrons is inversely proportional to the frequency of the incident light. In the light of above statements, choose the correct answer from the options given below
[13 April, 2023 (Shift-II)]
(a) Statement-I is true but Statement-II is false
(b) Both Statement-I and Statement-II are true
(c) Statement-I is false but Statement-II is true
(d) Both Statement-I and Statement-II are false

31. In photo electric effect
A. The photocurrent is proportional to the intensity of the incident radiation.
B. Maximum Kinetic energy with which photoelectrons are emitted depends on the intensity of incident light.
C. Max. K.E with which photoelectrons are emitted depends on the frequency of incident light.
D. The emission of photoelectrons require a minimum threshold intensity of incident radiation.
E. Max. K.E of the photoelectrons is independent of the frequency of the incident light.
Choose the correct answer from the options given below:
(a) A and C only (b) A and E only
(c) B and C only (d) A and B only
[08 April, 2023 (Shift-II)]

32. The threshold wavelength for photoelectric emission from a material is 5500Å. Photoelectrons will be emitted, when this material is illuminated with monochromatic radiation from a
A. 75 W infra-red lamp B. 10 W infra-red lamp
C. 75 W ultra-violet lamp D. 10 W ultra-violet lamp
Choose the correct answer from the options given below:
(a) B and C only (b) A and D only
(c) C only (d) C and D only
[29 Jan, 2023 (Shift-I)]

33. Given below are two statements:
Statement-I: Stopping potential in photoelectric effect does not depend on the power of the light source.
Statement-II: For a given metal, the maximum kinetic energy of the photoelectron depends on the wavelength of the incident light.
In light of the above statements, choose the most appropriate answer from the options given below.
(a) Statement-I is incorrect but Statement-II is correct
(b) Both Statement-I and Statement-II are incorrect
(c) Statement-I is correct but Statement-II is incorrect
(d) Both Statement-I and Statement-II are correct
[25 Jan, 2023 (Shift-II)]

34. The threshold frequency of metal is f_0. When the light of frequency $2f_0$ is, incident on the metal plate, the maximum velocity of photoelectron is v_1. When the frequency of incident radiation is increased to $5f_0$, the maximum velocity of photoelectrons emitted is v_2. The ratio of v_1 to v_2 is:
[01 Feb, 2023 (Shift-II)]
(a) $\frac{v_1}{v_2} = \frac{1}{2}$ (b) $\frac{v_1}{v_2} = \frac{1}{8}$ (c) $\frac{v_1}{v_2} = \frac{1}{16}$ (d) $\frac{v_1}{v_2} = \frac{1}{4}$

35. A Hydrogen-like atom has atomic number Z. Photons emitted in the electronic transitions from level $n = 4$ to level $n = 3$ in these atoms are used to perform photoelectric effect experiment on a target metal. The maximum kinetic energy of the photoelectrons generated is 1.95 eV. If the photoelectric threshold wavelength for the target metal is 310 nm, the value of Z is _____.
[Given: $hc = 1240$ eV-nm and $Rhc = 13.6$ eV, where R is the Rydberg constant, h is the Planck's constant and c is the speed of light in vacuum]
[JEE Adv, 2023]

36. The electric field at a point associated with a light wave is given by
$E = 200[\sin(6 \times 10^{15})t + \sin(9 \times 10^{15})t]$ Vm^{-1}
Given: $h = 4.14 \times 10^{-15}$ eVs
If this light falls on a metal surface having a work function of 2.50 eV, the maximum kinetic energy of the photoelectrons will be
(a) 1.90 eV (b) 3.27 eV (c) 3.60 eV (d) 3.42 eV
[29 June, 2022 (Shift-II)]

37. Given below are two statements: One is labelled as **Assertion (A)** and other is labelled as **Reason (R)**.
Assertion (A): The photoelectric effect does not takes place, if the energy of the incident radiation is less than the work function of a metal.
Reason (R): Kinetic energy of the photoelectrons is zero, if the energy of the incident radiation is equal to the work function of a metal.
In the light of the above statements, choose the most appropriate answer from the options given below.
(a) Both A and R are correct and R is the correct explanation of A
(b) Both A and R are correct but R is not the correct explanation of A
(c) A is correct but R is not correct
(d) A is not correct but R is correct
[29 June, 2022 (Shift-I)]

@FREE CBSE X @ YOUTUBE

38. The kinetic energy of emitted electron is E when the light incident on the metal has wavelength λ. To double the kinetic energy, the incident light must have wavelength: **[29 July, 2022 (Shift-I)]**

(a) $\frac{hc}{E\lambda - hc}$ (b) $\frac{hc\lambda}{E\lambda + hc}$ (c) $\frac{h\lambda}{E\lambda + hc}$ (d) $\frac{hc\lambda}{E\lambda - hc}$

39. A metal surface is illuminated by a radiation of wavelength 4500Å. The ejected photoelectron enters a constant magnetic field of 2 mT making an angle of 90° with the magnetic field. If it starts revolving in a circular path of radius 2mm, the work function of the metal is approximately: **[26 June, 2022 (Shift-II)]**

(a) 1.36 eV (b) 1.69 eV (c) 2.7 eV (d) 2.23 eV

40. Let K_1 and K_2 be the maximum kinetic energies of photo-electrons emitted when two monochromatic beams of wavelength λ_1 and λ_2, respectively are incident on a metallic surface. If $\lambda_1 = 3\lambda_2$ then: **[28 June, 2022 (Shift-II)]**

(a) $K_1 > \frac{K_2}{3}$ (b) $K_1 < \frac{K_2}{3}$

(c) $K_1 = \frac{K_2}{3}$ (d) $K_2 = \frac{K_1}{3}$

41. A metal exposed to light of wavelength 800 nm and and emits photoelectrons with a certain kinetic energy. The maximum kinetic energy of photo-electron doubles when light of wavelength 500 nm is used. The work function of the metal is: (Take $hc = 1230$ eV-nm). **[25 July, 2022 (Shift-I)]**

(a) 1.537 eV (b) 2.46 eV (c) 0.615 eV (d) 1.23 eV

42. With reference to the observations in photo-electric effect, identify the correct statements from below:

(A) The square of maximum velocity of photoelectrons varies linearly with frequency of incident light.

(B) The value of saturation current increases on moving the source of light away from the metal surface.

(C) The maximum kinetic energy of photo-electrons decreases on decreasing the power of LED (light emitting diode) source of light.

(D) The immediate emission of photo-electrons out of metal source can not be explained by particle nature of light / electromagnetic waves.

(E) Existence of threshold wavelength can not be explained by wave nature of light /electromagnetic waves. Choose the correct answer from the options gives below: **[27 July, 2022 (Shift-II)]**

(a) (A) and (B) only (b) (A) and (E) only
(c) (C) and (E) only (d) (D) and (E) only

43. Two streams of photons, possessing energies equal to five and ten times the work function of metal are incident on the metal surface successively. The ratio of maximum velocities of the photoelectron emitted, in the two cases respectively, will be **[28 July, 2022 (Shift-II)]**

(a) 1 : 2 (b) 1 : 3 (c) 2 : 3 (d) 3 : 2

44. The light of two different frequencies whose photons have energies 3.8 eV and 1.4 eV respectively, illuminate a metallic surface whose work function is 0.6 eV successively. The ratio of maximum speed of emitted electrons for the two frequencies respectively will be: **[24 June, 2022 (Shift-II)]**

(a) 1 : 1 (b) 2 : 1 (c) 4 : 1 (d) 1 : 4

45. When light of frequency twice the threshold frequency is incident on the metal plate, the maximum velocity of emitted electron is v_1. When the frequency of incident radiation is increased to five times the threshold value, the maximum velocity of emitted electron becomes v_2. If $v_2 = xv_1$, the value of x will be _____. **[24 June, 2022 (Shift-I)]**

46. The stopping potential for photoelectrons emitted from a surface illuminated by light of wavelength 6630 Å is 0.42 V. If the threshold frequency is $x \times 10^{13}$/s, where x is (nearest integer). (Given, speed light = 3×10^8 m/s, Planck's constant = 6.63×10^{-34} Js) **[26 June, 2022 (Shift-II)]**

47. When light of a given wavelength is incident on a metallic surface, the minimum potential needed to stop the emitted photoelectrons is 6.0 V. This potential drops to 0.6 V if another source with wavelength four times that of the first one and intensity half of the first one is used. What are the wavelength of the first source and the work function of the metal, respectively? [Take $\frac{hc}{e} = 1.24 \times 10^{-6}$ J mC^{-1}.] **[JEE Adv, 2022]**

(a) 1.72×10^{-7} m, 1.20 eV (b) 1.72×10^{-7} m, 5.60 eV
(c) 3.78×10^{-7} m, 5.20 eV (d) 3.78×10^{-7} m, 1.20 eV

48. The stopping potential for electrons emitted from a photosensitive surface illuminated by light of wavelength 491 nm is 0.710 V. When the incident wavelength is changed to a new value, the stopping potential is 1.43 V. The new wavelength is: **[25 Feb, 2021 (Shift-II)]**

(a) 382 nm (b) 309 nm (c) 329 nm (d) 400 nm

49. Two identical photocathodes receive the light of frequencies f_1 and f_2 respectively. If the velocities of the photo-electrons coming out are v_1 and v_2 respectively, then **[17 March, 2021 (Shift-II)]**

(a) $v_1^2 - v_2^2 = \frac{2h}{m}[f_1 - f_2]$ (b) $v_1^2 + v_2^2 = \frac{2h}{m}[f_1 + f_2]$

(c) $v_1 + v_2 = \left[\frac{2h}{m}(f_1 + f_2)\right]^{\frac{1}{2}}$ (d) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{\frac{1}{2}}$

50. The radiation corresponding to $3 \rightarrow 2$ transition of a hydrogen atom falls on a gold surface to generate photoelectrons. These electrons are passed through a magnetic field of 5×10^{-4} T. Assume that the radius of the largest circular path followed by these electrons is 7mm, the work function of the metal is: (Mass of electron = 9.1×10^{-31} kg) **[20 July, 2021 (Shift-I)]**

(a) 0.82 eV (b) 1.88 eV (c) 1.36 eV (d) 0.16 eV

51. In a photoelectric experiment, increasing the intensity of incident light: **[27 Aug, 2021 (Shift-I)]**

(a) Increases the number of photons incident and also increases the K.E. of the ejected electrons.

(b) Increases the number of photons incident and the K.E. of the ejected electrons remains unchanged.

(c) Increases the frequency of photons incident and increases the K.E. of the ejected electrons.

(d) Increases the frequency of photons incident and the K.E. of the ejected electrons remains unchanged

52. The stopping potential in the context of photoelectric depends on the following property of incident electromagnetic radiation: **[16 March, 2021 (Shift-I)]**

(a) Frequency (b) Amplitude (c) Intensity (d) Phase

53. An electron and proton are separated by a large distance. The electron starts approaching the proton with energy 3eV. The proton captures the electron and forms a hydrogen atom in second excited state. The resulting photon is incident on a photosensitive metal of threshold wavelength 4000Å. What is the maximum kinetic energy of the emitted photoelectron? **[27 July, 2021 (Shift-II)]**

(a) 1.41eV
(b) 7.61eV
(c) 3.3eV
(d) No photoelectron would be emitted

@MAKE_CBSE_EASY @RAJ_EDUCARE

54. In a photoelectric experiment ultraviolet light of wavelength 280 nm is used with lithium cathode having work function $\phi = 2.5$eV. If the wavelength of incident light is switched to 400nm, find out the change in the stopping potential. ($h = 6.63 \times 10^{-34}$ Js, $c = 3 \times 10^8 ms^{-1}$)
(a) 1.3 V (b) 1.1 V (c) 0.6 V (d) 1.9 V
[26 Aug, 2021 (Shift-I)]

55. A monochromatic neon lamp with wavelength of 670.5 nm illuminates a photo-sensitive material which has a stopping voltage of 0.48 V. What will be the stopping voltage if the source light is changed with another source of wavelength of 474.6 nm?
(a) 1.5 V (b) 0.24 V (c) 0.96 V (d) 1.25 V
[27 Aug, 2021 (Shift-II)]

56. When radiation of wavelength λ is incident on a metallic surface, the stopping potential of ejected photoelectrons is 4.8 V. If the same surface is illuminated by radiation of double the previous wavelength, then the stopping potential becomes 1.6 V. The threshold wavelength of the metal is:
(a) 6λ (b) 8λ (c) 2λ (d) 4λ
[25 July, 2021 (Shift-II)]

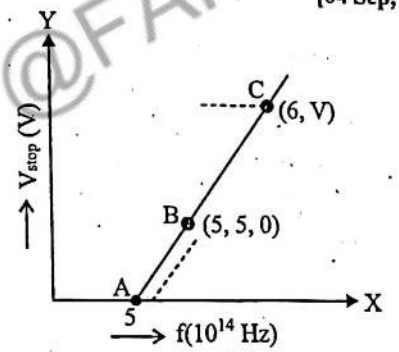
57. A certain metallic surface is illuminated by monochromatic radiation of wavelength λ. The stopping potential for photoelectric current for this radiation is $3V_0$. If the same surface is illuminated with a radiation of wavelength 2λ, the stopping potential is V_0. The threshold wavelength of this surface for photoelectric effect is _____ λ.
[20 July, 2021 (Shift-II)]

58. Two stream of photons, possessing energies equal to twice and ten times the work function of metal are incident on the metal surface successively. The value of ratio of maximum velocities of the photoelectrons emitted in the two respective cases is $x : y$. The value of x is _____.
[26 Feb, 2021 (Shift-II)]

59. When the wavelength of radiation falling on a metal is charged from 500 nm to 200 nm the maximum kinetic energy of the photoelectrons becomes three times larger. The work function of the metals is close to:
(a) 1.02 eV (b) 0.61 eV (c) 0.52 eV (d) 0.81 eV
[03 Sep, 2020 (Shift-I)]

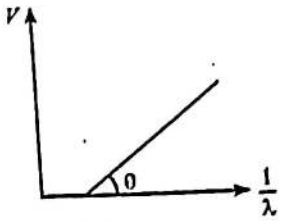
60. Radiation, with wavelength 6561 Å falls on a metal surface to produce photoelectrons. The electrons are made to enter a uniform magnetic field of 3×10^{-4} T. If the radius of the largest circular path followed by the electrons is 10 mm, the work function of the metal is close to
(a) 1.8 eV (b) 0.8 eV (c) 1.6 eV (d) 1.1 eV
[09 Jan, 2020 (Shift-I)]

61. Given figure shows few data points in a photo electric effect experiment for a certain metal. The minimum energy for ejection of electron from its surface is (Planck's constant h = 6.62×10^{-34} Js)
[04 Sep, 2020 (Shift-I)]



(a) 2.59 eV (b) 2.27 eV (c) 1.93 eV (d) 2.10 eV

62. In photoelectric effect experiment, the graph of stopping potential V versus reciprocal of wavelength obtained is shown in the figure. As the intensity of incident radiation is increased:
[04 Sep, 2020 (Shift-II)]



(a) Slope of the straight line get more steep
(b) Straight line shifts to left
(c) Straight line shifts to right
(d) Graph does not change

63. When photon of energy 4.0 eV strikes the surface of a metal A, the ejected photoelectrons have maximum kinetic energy T_A eV and de-Broglie wavelength λ_A. The maximum kinetic energy of photoelectrons liberated from another metal B by photon of energy 4.50 eV is $T_B = (T_A - 11.5)$eV. If the de-Broglie wavelength of these photoelectrons $\lambda_B = 2\lambda_A$, the work function of metal B is
(a) 4 eV (b) 1:5 eV (c) 2 eV (d) 3 eV
[08 Jan, 2020 (Shift-I)]

64. With increasing biasing voltage of a photodiode, the photocurrent magnitude:
(a) remains constant
(b) increases initially and after attaining
(c) increases linearly
(d) increases initially and saturates finally
[05 Sep, 2020 (Shift-I)]

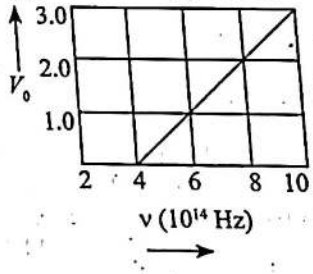
65. The surface of a metal is illuminated alternately with photons of energies $E_1 = 4$ eV and $E_2 = 2.5$ eV respectively. The ratio of maximum speeds of the photoelectrons emitted in the two cases is 2. The work function of the metal in (eV) is _____.
[05 Sep, 2020 (Shift-II)]

66. When radiation of wavelength λ is used to illuminate a metallic surface, the stopping potential is V. When the same surface is illuminated with radiation of wavelength 3λ, the stopping potential is $\frac{V}{4}V$. If the threshold wavelength for the metallic surface is $n\lambda$ then value of n will be
[2 Sep, 2020 (Shift-I)]

67. A beam of electromagnetic radiation of intensity 6.4×10^{-5} W/cm^2 is comprised of wavelength, $\lambda = 310$ nm. It falls normally on a metal (work function $\varphi = 2$ eV) of surface area 1 cm^2. If one in 10^3 photons ejects an electron, total number of electrons ejected in is 10^x. ($hc = 1240$ eVnm, 1 eV = 1.6×10^{-19} J), then x is _____.
[7 Jan, 2020 (Shift-I)]

68. The stopping potential V_0 (in volt) as a function of frequency (ν) for a sodium emitter, is shown in the figure. The work function of sodium, from the data plotted in the figure, will be :
[12 April, 2019 (Shift-I)]

(Given : Planck's constant (h) = 6.63×10^{-34} Js, electron charge e = $1.6 \times 10^{-19}C$)
(a) 1.82e V (b) 1.66e V (c) 2.12e V (d) 195e V



@FAKHOOR_X_@JEEDUNET

69. The electric field of light wave is given as

$\vec{E} = 10^{-3}\cos\left(\frac{2\pi x}{5\times10^{-7}} - 2\pi\times6\times10^{14}t\right)\hat{x}\frac{N}{C}$

$\vec{E} = 10^{-3}\cos\left(\frac{2\pi x}{5\times10^{-7}} - 2\pi\times6\times10^{14}t\right)\hat{x}\frac{N}{C}$. This light falls on a metal plate of work function 2 eV. The stopping potential of the photoelectrons is

Given: E (in eV) $= \frac{12375}{\lambda(\text{in Å})}$ **[9 April, 2019 (Shift-I)]**

(a) 0.48 V (b) 2.0 V (c) 2.48 V (d) 0.72 V

70. A metal plate of area 1×10^{-4} m² is illuminated by a radiation of intensity 16 mW/m². The work function of the metal is 5 eV. The energy of the incident photons is 10 eV and only 10% of it produces photo electrons. The number of emitted photo electrons per second and their maximum energy, respectively, will be: [1 eV = 1.6×10^{-19} J] **[10 Jan, 2019 (Shift-II)]**

(a) 10^{14} and 10 eV (b) 10^{12} and 5 eV
(c) 10^{11} and 5 eV (d) 10^{10} and 5 eV

71. Surface of certain metal is first illuminated with light of wavelength $\lambda_1 = 350$ nm and then the light of wavelength $\lambda_2 = 540$ nm. It is found that the maximum speed of the photo electrons in the two cases differ by a factor of 2. The work function of the metal (in eV) is close to **[9 Jan, 2019 (Shift-I)]**

(Energy of photon $= \frac{1240}{\lambda(\text{in nm})} eV$)

(a) 1.8 (b) 2.5 (c) 5.6 (d) 1.4

72. When a certain photosensitive surface is illuminated with monochromatic light of frequency ν, the stopping potential for the photo current is $-V_0/2$. When the surface is illuminated by monochromatic light of frequency $\nu/2$, the stopping potential is $-V_0$. The threshold frequency for photoelectric emission is: **[12 Jan, 2019 (Shift-II)]**

(a) $\frac{5\nu}{3}$ (b) $\frac{4}{3}\nu$ (c) 2ν (d) $\frac{3\nu}{2}$

73. The magnetic field associated with a light wave is given, at the origin, by

$B = B_0[\sin(3.14 \times 10^7)ct + \sin(6.28 \times 10^7)ct]$

If this light falls on a silver plate having a work function of 4.7 eV, what will be the maximum kinetic energy of the photo electrons? **[9 Jan, 2019 (Shift-II)]**

(a) 6.82 eV (b) 12.5 eV (c) 8.52 eV (d) 7.67 eV

74. In a photoelectric effect experiment the threshold wavelength of light is 380 nm. If the wavelength of incident light is 260 nm, the maximum kinetic energy of emitted electrons will be **[10 April, 2019 (Shift-I)]**

(a) 1.5 eV (b) 4.5 eV (c) 15.1 eV (d) 3.0 eV

75. In a photoelectric experiment, the wavelength of the light incident on a metal is changed from 300 nm to 400 nm. The decrease in the stopping potential is close to $\left(\frac{hc}{e} = 1240\ nm - V\right)$ **[11 Jan, 2019 (Shift-II)]**

(a) 0.5V (b) 1.5V (c) 1.0V (d) 2.0V

76. Light is incident normally on a completely absorbing surface with an energy flux of 25 $W\,cm^{-2}$. If the surface has an area of 25 cm^2, the momentum transferred to the surface in 40 min time duration will be **[10 April, 2019 (Shift-II)]**

(a) 6.3×10^{-4} Ns (b) 3.5×10^{-6} Ns
(c) 5.0×10^{-3} Ns (d) 1.4×10^{-6} Ns

77. The electric field in a plane electromagnetic wave is given by

$\vec{E} = 200\cos\left[\left(\frac{0.5\times10^3}{m}\right)x - \left(1.5\times10^{11}\frac{rad}{s}\times t\right)\right]\frac{V}{m}\hat{j}$

If this wave falls normally on a perfectly reflecting surface having an area of 100 cm^2. If the radiation pressure exerted by the E.M. wave on the surface during a 10 minute exposure is $\frac{x}{10^9}\frac{N}{m^2}$. Find the value of x **[26 Aug, 2021 (Shift-I)]**

De-Broglie Wavelength

78. The de-Broglie wavelength of an electron is the same as that of a photon. If velocity of electron is 25% of the velocity of light, then the ratio of K.E. of electron and K.E. of photon will be: **[29 Jan, 2024 (Shift-I)]**

(a) $\frac{1}{1}$ (b) $\frac{1}{8}$ (c) $\frac{8}{1}$ (d) $\frac{1}{4}$

79. The de Broglie wavelengths of a proton and an α particle are λ and 2λ respectively. The ratio of the velocities of proton and α particle will be: **[1 Feb, 2024 (Shift-I)]**

(a) 1 : 8 (b) 1 : 2 (c) 4 : 1 (d) 8 : 1

80. A proton and an electron are associated with same de-Broglie wavelength. The ratio of their kinetic energies is: (Assume $h = 6.63 \times 10^{-34}$ J s, $m_e = 9.0 \times 10^{-31}$ kg and $m_p = 1836$ times m_e) **[08 April, 2024 (Shift-I)]**

(a) 1 : 1836 (b) $1 : \frac{1}{1836}$ (c) $1 : \frac{1}{\sqrt{1836}}$ (d) $1 : \sqrt{1836}$

81. A proton and an electron have the same de Broglie wavelength. If K_p and K_e be the kinetic energies of proton and electron respectively. Then choose the correct relation: [08 April, 2024 (Shift-II)]

(a) $K_p > K_e$ (b) $K_p = K_e$ (c) $K_p = K_e^2$ (d) $K_p < K_e$

82. A proton, an electron and an alpha particle have the same energies. Their de-Broglie wavelengths will be compared as: **[09 April, 2024 (Shift-I)]**

(a) $\lambda_e > \lambda_\alpha > \lambda_p$ (b) $\lambda_\alpha < \lambda_p < \lambda_e$
(c) $\lambda_p < \lambda_e < \lambda_\alpha$ (d) $\lambda_p > \lambda_e > \lambda_\alpha$

83. The de-Broglie wavelength associated with a particle of mass m and energy E is $h/\sqrt{2\,mE}$. The dimensional formula for Planck's constant is: **[09 April, 2024 (Shift-II)]**

(a) $[ML^{-1}T^{-2}]$ (b) $[ML^2T^{-1}]$ (c) $[MLT^{-2}]$ (d) $[M^2L^2T^{-2}]$

84. Electron beam used in an electron microscope, accelerated by a voltage of 20kV has a de-Broglie wavelength of λ_0. If the voltage is increased to 40kV then the de-Broglie wavelength associated with the electron beam would be: **[25 Jan, 2023 (Shift-I)]**

(a) $3\lambda_0$ (b) $9\lambda_0$ (c) $\frac{\lambda_0}{2}$ (d) $\frac{\lambda_0}{\sqrt{2}}$

85. An α-particle, a proton and an electron have the same kinetic energy. Which one of the following is correct in case of their De-Broglie wavelength: **[24 Jan, 2023 (Shift-II)]**

(a) $\lambda_\alpha > \lambda_p > \lambda_e$ (b) $\lambda_\alpha < \lambda_p < \lambda_e$
(c) $\lambda_\alpha = \lambda_p = \lambda_e$ (d) $\lambda_\alpha > \lambda_p < \lambda_e$

@FAKE_CBSE_X@RAJ_EDUNET

86. If the ratio of de-Broglie wavelength of an α-particle and a proton accelerated from rest by the same potential is $\frac{1}{\sqrt{m}}$, then the value of m is
[29 Jan, 2023 (Shift-II)]
(a) 4 (b) 16 (c) 8 (d) 2

87. The de Broglie wavelength of a molecule in a gas at room temperature (300 K) is λ_1. If the temperature of the gas is increased to 600 K, then the de Broglie wavelength of the same gas molecule becomes
[10 Apr, 2023 (Shift-I)]
(a) $\frac{1}{\sqrt{2}}\lambda_1$ (b) $2\lambda_1$ (c) $\frac{1}{2}\lambda_1$ (d) $\sqrt{2}\lambda_1$

88. A proton and an α-particle are accelerated from rest by 2V and 4V potentials, respectively. The ratio of their de-Broglie wavelength is:
[12 April 2023 (Shift-I)]
(a) 4 : 1 (b) 2 : 1 (c) 8 : 1 (d) 16 : 1

89. The de Broglie wavelength of an electron having kinetic energy E is λ. If the kinetic energy of electron becomes $\frac{E}{4}$, then its de-Broglie wavelength will be :
[15 April, 2023 (Shift-I)]
(a) $\frac{1}{\sqrt{2}}$ (b) $\frac{1}{2}$ (c) 2λ (d) $\sqrt{2}\lambda$

90. A proton moving with one tenth of velocity of light has a certain de Broglie wavelength of λ. An alpha particle having certain kinetic energy has the same de-Broglie wavelength λ. The ratio of kinetic energy of proton and that of alpha particle is:
[01 Feb, 2023 (Shift-I)]
(a) 2 : 1 (b) 4 : 1 (c) 1 : 2 (d) 1 : 4

91. Given below are two statements: One is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**
Assertion (A): A beam of electrons shows wave nature and exhibit interference and diffraction.
Reason (R): Davisson and Germer experimentally verified the wave nature of electrons.
In the light of the above statements. Choose the most appropriate answer from the options given below:
[31 Jan, 2023 (Shift-I)]
(a) A is correct but R is not correct
(b) A is not correct but R is correct
(c) Both A and R are correct but R is Not the correct explanation of A
(d) Both A and R are correct and R is the correct explanation of A

92. The ratio of the de-Broglie wavelengths of proton and electron having same kinetic energy:
(Assume $m_p = m_e \times 1849$)
[11 April, 2023 (Shift-II)]
(a) 1 : 43 (b) 1 : 30 (c) 1 : 63 (d) 2 : 43

93. An electron accelerated through a potential difference V_1 has a de-Broglie wavelength of λ. When the potential is changed to V_2, its de-Broglie wavelength increases by 50%. The value of $\left(\frac{V_1}{V_2}\right)$ is equal to:
[30 Jan, 2023 (Shift-II)]
(a) 3 (b) $\frac{9}{4}$ (c) $\frac{3}{2}$ (d) 4

94. The kinetic energy of an electron, α-particle and a proton are given as $4K$, $2K$ and K respectively. The de-Broglie wavelength associated with electron (λ_e) α-particle (λ_α) and the proton (λ_p) are as follows:
[06 April, 2023 (Shift-I)]
(a) $\lambda_\alpha = \lambda_p < \lambda_e$ (b) $\lambda_\alpha > \lambda_p < \lambda_e$
(c) $\lambda_\alpha < \lambda_p < \lambda_e$ (d) $\lambda_\alpha = \lambda_p > \lambda_e$

95. Proton (p) and electron (e) will have same deBroglie wavelength when the ratio of their momentum is (assume, $m_p = 1849 m_e$)
[08 April, 2023 (Shift-I)]
(a) 1 : 43 (b) 43 : 1 (c) 1 : 1849 (d) 1 : 1

96. The de Broglie wavelengths for an electron and a photon are λ_e and λ_p respectively. For the same kinetic energy of electron and photon, which of the following presents the correct relation between the de Broglie wavelengths of two
[28 June, 2022 (Shift-I)]
(a) $\lambda_p \propto \lambda_e^2$ (b) $\lambda_p \propto \lambda_e$
(c) $\lambda_p \propto \sqrt{\lambda_e}$ (d) $\lambda_p \propto \sqrt{\frac{1}{\lambda_e}}$

97. The ratio of wavelengths of proton and deuteron accelerated by potential V_p and V_d is 1: $\sqrt{2}$. Then, the ratio of V_p to V_d will be:
[25 July, 2022 (Shift-II)]
(a) 1 : 1 (b) $\sqrt{2}$:1
(c) 2 : 1 (d) 4 : 1

98. A nucleus of mass M at rest splits into two parts having masses $\frac{M'}{3}$ and $\frac{2M'}{3}$ ($M < M$), The ratio of de Broglie wavelength of two parts will be:
[26 July, 2022 (Shift-II)]
(a) 1 : 2 (b) 2 : 1 (c) 1 : 1 (d) 2 : 3

99. An α particle and a proton are accelerated from rest through the same potential difference. The ratio of linear momenta acquired by above two particals will be:
[29 July, 2022 (Shift-II)]
(a) $\sqrt{2}$:1 (b) $2\sqrt{2}$:1 (c) $4\sqrt{2}$:1 (d) 8 : 1

100. An α particle and a carbon 12 atom has same kinetic energy K. The ratio of their de-Broglie wavelengths ($\lambda_\alpha : \lambda_{C12}$) is:
[27 June, 2022 (Shift-I)]
(a) $1:\sqrt{3}$ (b) $\sqrt{3}:1$ (c) 3 : 1 (d) $2:\sqrt{3}$

101. Given below are two statements:
Statements-I: Davission-Germer experiment establishes the wave nature of electrons.
Statements-II: If electrons have wave nature, they can interfere and show diffraction.
In the light of the above statements choose the correct answer from the option given below:
[25 June, 2022 (Shift-I)]
(a) Both Statement I and Statement II are true.
(b) Both Statement I and Statement II are false.
(c) Statement I is true but Statement II is false.
(d) Statement I is false but Statement II is true.

102. A proton, a neutron, an electron and a α-particle have same energy. If $\lambda_p, \lambda_n, \lambda_e$ and λ_α are the de-Broglie's wavelengths of proton, electron and an α-particle respectively, then choose the correct relation from the following
[25 June, 2022 (Shift-II)]
(a) $\lambda_p = \lambda_n > \lambda_e > \lambda_\alpha$ (b) $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$
(c) $\lambda_e < \lambda_p = \lambda_n > \lambda_\alpha$ (d) $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

103. An electron with speed v and a photon with speed c have the same de-Broglie wavelength. If the kinetic energy and momentum of electron are E_e and p_e and that of photon are E_{ph} and p_{ph} respectively. Which of the following is correct?
[26 June, 2022 (Shift-I)]
(a) $\frac{E_e}{E_{ph}} = \frac{2c}{v}$ (b) $\frac{E_e}{E_{ph}} = \frac{v}{2c}$ (c) $\frac{p_e}{p_{ph}} = \frac{2c}{v}$ (d) $\frac{p_e}{p_{ph}} = \frac{v}{2c}$

@TAKE CBSE X OR I EDUNET

104. An electron (mass m) with an initial velocity $\vec{v} = v_0\hat{i}\,(v_0 > 0)$ is moving in an electric field $\vec{E} = -E_0\hat{i}\,(E_0 > 0)$ where E_0 is constant. If at $t = 0$ de Broglie wavelength is $\lambda_0 = \frac{h}{mv_0}$, then its dc Broglie wavelength after time t is given by **[27 July, 2022 (Shift-I)]**

(a) λ_0 (b) $\lambda_0\left(1+\frac{eE_0t}{mv_0}\right)$

(c) $\lambda_0 t$ (d) $\frac{\lambda_0}{\left(1+\frac{eE_0t}{mv_0}\right)}$.

105. The equation $\lambda = \frac{1.227}{x}$ nm can be used to find the de-Brogli wavelength of an electron. In this equation x stands for:
Where m = mass of electron **[28 July, 2022 (Shift-I)]**
P = momentum of electron
K = kinetic energy of electron
V = Accelerating potential in volts for electron

(a) $\sqrt{mK}$ (c) $\sqrt{K}$ (b) $\sqrt{P}$ (d) $\sqrt{V}$

106. An X-ray tube is operated at 1.24 million volt. The shortest wavelength of the produced photon will be: **[24 Feb, 2021 (Shift-II)]**
(a) 10^{-4} nm (b) 10^{-3} nm (c) 10^{-1} nm (d) 10^{-2} nm

107. A particle of mass 9.1×10^{-31} kg travels in a medium with a speed of 10^6 m/s and a photon of a radiation of linear momentum 10^{-27} kg m/ s travels in vacuum. The wavelength of photon is _____ times the wavelength of the particle. **[27 July, 2021 (Shift-I)]**

108. An electron of mass m and a photon have same energy E. The ratio of wavelength of electron to that of photon is : (c being the velocity of light) **[17 March, 2021 (Shift-I)]**

(a) $\frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$ (b) $\left(\frac{E}{2m}\right)^{1/2}$

(c) $c(2mE)^{\frac{1}{2}}$ (d) $\frac{1}{c}\left(\frac{2m}{E}\right)^{1/2}$

109. Consider two separate ideal gases of electrons and protons having same number of particles.
The temperature of both the gases are same. The ratio of the uncertainty in determining the position of an electron to that of a proton is proportional to: **[31 Aug, 2021 (Shift-II)]**

(a) $\sqrt{\frac{m_e}{m_p}}$ (b) $\sqrt{\frac{m_p}{m_e}}$ (c) $\frac{m_p}{m_e}$ (d) $\left(\frac{m_p}{m_e}\right)^{3/2}$

110. An electron having de-Broglie wavelength λ is incident on a target in a X-ray tube. Cut-off wavelength of emitted X-ray is:
[20 July, 2021 (Shift-II)]

(a) 0 (b) $\frac{2mc\lambda^2}{h}$ (c) $\frac{hc}{mc}$ (d) $\frac{2m^2c^2\lambda^2}{h^2}$

111. An α particle and a proton are accelerated from rest by a potential difference of 200 V. After this, their de Broglie wavelengths are λ_α and λ_p respectively. The ratio $\frac{\lambda_p}{\lambda_\alpha}$ is: **[25 Feb, 2021 (Shift-I)]**

(a) 3.8 (b) 7.8 (c) 2.8 (d) 8

112. An electron of mass m_e and a proton of mass m_p are accelerated through the same potential difference. The ratio of the de-Broglie wavelength associated with the electron to that with the proton is:
[22 July, 2021 (Shift-II)]

(a) $\frac{m_p}{m_e}$ (b) 1 (c) $\frac{m_e}{m_p}$ (d) $\sqrt{\frac{m_p}{m_e}}$

113. An electron moving with speed v and a photon moving with speed c, have same D-Broglie wavelength. The ratio of kinetic energy of electron to that of photon is: **[25 July, 2021 (Shift-II)]**

(a) $\frac{v}{2c}$ (b) $\frac{2c}{v}$ (c) $\frac{v}{3c}$ (d) $\frac{3c}{v}$

114. The de-Broglie wavelength of a particle having kinetic energy E is λ. How much extra energy must be given to this particle so that the de-Broglie wavelength reduces to 75% of the initial value?
[26 Aug, 2021 (Shift-II)]

(a) $\frac{1}{9}E$ (b) E (c) $\frac{16}{9}E$ (d) $\frac{7}{9}E$

115. What should be the order of arrangement of de-Broglie wavelength of electron (λ_e), an α-particle (λ_α) and proton (λ_p) given that all have the same kinetic energy? **[25 July, 2021 (Shift-I)]**
(a) $\lambda_e = \lambda_p = \lambda_\alpha$ (b) $\lambda_e < \lambda_p < \lambda_\alpha$
(c) $\lambda_e = \lambda_p > \lambda_\alpha$ (d) $\lambda_e > \lambda_p > \lambda_\alpha$

116. The temperature of an ideal gas in 3-dimensions is 300 K. The corresponding de-Broglie wavelength of the electron approximately at 300 K, is:
[m_e = mass of electron = 9×10^{-31} kg
h = Planck constant = 6.6×10^{-34} Js
k_B = Boltzmann constant = 1.38×10^{-23} JK^{-1}]
[1 Sept, 2021 (Shift-II)]
(a) 3.25 nm (b) 6.26 nm (c) 2.26 nm (d) 8.46 nm

117. A moving proton and electron have the same de-Broglie wavelength. If K and P denote the K.E. and momentum respectively. Then choose the correct option: **[31 Aug, 2021 (Shift-I)]**
(a) $K_p = K_e$ and $P_p = P_e$ (b) $K_p < K_e$ and $P_p < P_e$
(c) $K_p < K_e$ and $P_p = P_e$ (d) $K_p > K_e$ and $P_p = P_e$

118. An electron of mass m_e and a proton of mass $m_p = 1836\, m_e$ are moving with the same speed. The ratio of their de Broglie wavelength $\frac{\lambda_{electron}}{\lambda_{proton}}$ will be: **[25 Feb, 2021 (Shift-II)]**

(a) 1 (b) 918 (c) $\frac{1}{1836}$ (d) 1836

119. The de-Broglie wavelength associated with an electron and a proton were calculated by accelerating them though same potential of 100 V. What should nearly be the ratio of their wavelengths? (m_p = 1.00727 μ, $m_e = 0.00055\ u$) **[16 March, 2021 (Shift-II)]**
(a) 1860 : 1 (b) $(1860)^2$: 1
(c) 41.4 : 1 (d) 43 : 1

120. A particle is traveling 4 times as fast as an electron. Assuming the ratio of de-Broglie wavelength of a particle to that of electron is 2: 1, the mass of the particle is: **[18 March, 2021 (Shift-I)]**

(a) $\frac{1}{16}$ times the mass of e$^-$ (b) 8 times the mass of e$^-$

(c) $\frac{1}{8}$ times the mass of e$^-$ (d) 16 times the mass of e

@TAKE_CBSE_@RAJEDUNET

121. The de Broglie wavelength of a proton and α-particle are equal. The ratio of their velocities is:
(a) 4:2 (b) 4 :3 (c) 4 :1 (d) 1:4 [24 Feb, 2021 (Shift-II)]

122. Given below are two statements: One is labelled as **Assertion (A)** and the other is labeled as **Reason (R)**. [26 Feb, 2021 (Shift-I)]
Assertion (A): An electron microscope achieve better resolving power than an optical microscope.
Reason (R): The de Broglie's wavelength of the electrons emitted from an electron gun is much less than wavelength of visible light.
In the light of the above statements, choose the correct answer from the options given below:
(a) A is true but R is false.
(b) A is false but R is true.
(c) Both A and R are true and R is the correct explanation of A.
(d) Both A and R are true but R is not the correct explanation of A.

123. A particle of mass 4M at rest disintegrates into two particles of mass M and 3M respectively having non zero velocities. The ratio of de-Broglie wavelength of particle of mass M to that of mass 3M will be:
(a) 3 : 1 (b) 1 : 1 (c) 1 : 3 (d) $1:\sqrt{3}$ [25 July, 2021 (Shift-I)]

124. A particle is moving 5 times as fast as an electron. The ratio of the de-Broglie wavelength of the particle to that of the electron is 1.878×10^{-4}. The mass of the particle is close to:
(a) 9.7×10^{-28} kg (b) 4.8×10^{-27} kg
(c) 1.2×10^{-28} kg (d) 9.1×10^{-31} kg [02 Sep, 2020 (Shift-II)]

125. An electron (of mass m) and a photon have the same energy E in the range of a few eV. The ratio of the de-Broglie wavelength associated with the electron and the wavelength of the photon is (c = speed of light in vacuum)
(a) $\frac{1}{c}\left(\frac{2E}{m}\right)^{\frac{1}{2}}$ (b) $\left(\frac{E}{2m}\right)^{\frac{1}{2}}$ (c) $c(2mE)^{\frac{1}{2}}$ (d) $\frac{1}{c}\left(\frac{E}{2m}\right)^{\frac{1}{2}}$ [07 Jan, 2020 (Shift-II)]

126. An electron of mass m and magnitude of charge $|e|$ initially at rest gets accelerated by a constant electric field E. The rate of change of de-Broglie wavelength of this electron at time t ignoring relativistic effects is
(a) $-\frac{h}{|e|Et}$ (b) $-\frac{h}{|e|E\sqrt{t}}$
(c) $-\frac{h}{|e|Et^2}$ (d) $\frac{|e|Et}{h}$ [9 Jan, 2020 (Shift-II)]

127. Particle A of mass $m_A = \frac{m}{2}$ moving along the x-axis with velocity v_0 collides elastically with another particle B at rest having mass $m_B = \frac{m}{3}$.
If both particles move along the x-axis after the collision, the change $\Delta\lambda$ in de-Broglie wavelength of particle A, in terms of its de-Broglie wavelength (λ_0) before collision is [04 Sep, 2020 (Shift-I)]
(a) $\Delta\lambda = 2\lambda_0$ (b) $\Delta\lambda = 4\lambda_0$
(c) $\Delta\lambda = \frac{3}{2}\lambda_0$ (d) $\Delta\lambda = \frac{5}{2}\lambda_0$

128. A particle moving with kinetic energy E has de-Broglie wavelength λ. If energy ΔE is added to its energy, the wavelength become $\lambda/2$. Value of ΔE, is
(a) $4E$ (b) $3E$ (c) $2E$ (d) E [9 Jan, 2020 (Shift-I)]

129. An electron, a doubly ionized helium ion (He^{++}) and a proton are having the same kinetic energy. The relation between their respective de-Broglie wavelengths $\lambda_e, \lambda_{He^{++}}$ and λ_p is
(a) $\lambda_e > \lambda_{He^{++}} > \lambda_p$ (b) $\lambda_e < \lambda_p < \lambda_{He^{++}}$
(c) $\lambda_e > \lambda_p > \lambda_{He^{++}}$ (d) $\lambda_e < \lambda_{He^{++}} = \lambda_p$ [06 Sep, 2020 (Shift-I)]

130. An electron (mass m) with initial velocity $\vec{v} = v_0\hat{i} + v_0\hat{j}$ is in an electric field $\vec{E} = -E_0\hat{k}$. If λ_0 is initial de-Broglie wavelength of electron, its de-Broglie wavelength at time t is given by
(a) $\frac{\lambda_0}{\sqrt{1+\frac{e^2E_0^2t^2}{2m^2v_0^2}}}$ (b) $\frac{\lambda_0}{\sqrt{2+\frac{e^2E^2t^2}{m^2v_0^2}}}$
(c) $\frac{\lambda_0\sqrt{2}}{\sqrt{1+\frac{e^2E^2t^2}{m^2v_0^2}}}$ (d) $\frac{\lambda_0}{\sqrt{1+\frac{e^2E^2t^2}{m^2v_0^2}}}$ [08 Jan, 2020 (Shift-II)]

131. Assuming the nitrogen molecule is moving with r.m.s. velocity at 400 K, the de-Broglie wavelength of nitrogen molecule is close to
(Given nitrogen molecule weight: 4.64×10^{-26} kg, Boltzman constant: 1.38×10^{-23} J/K, Planck constant: 6.63×10^{-34} Js.)
(a) 0.24 Å (b) 0.20 Å (c) 0.34 Å (d) 0.44 Å [06 Sep, 2020 (Shift-II)]

132. Consider an electron in a hydrogen atom, revolving in its second excited state (having radius 4.65Å). The de-Broglie wavelength of this electron is :
(a) 12.9 Å (b) 9.7 Å (c) 6.6 Å (d) 3.5 Å [12 April, 2019 (Shift-II)]

133. In a Frank-hertz experiment, an electron of energy 5.6 eV passes through mercury vapour and emerges with an energy 0.7 eV. The minimum wavelength of photons emitted by mercury atoms is close to :
(a) 1700 nm (b) 2020 nm (c) 220 nm (d) 250 nm [12 Jan, 2019 (Shift-II)]

134. Two particles move at right angle to each other. Their de-Broglie wavelengths are λ_1 and λ_2 respectively. The particles suffer perfectly inelastic collision. The de-Broglie wavelength λ, of the final particle, is given by
(a) $\lambda = \frac{\lambda_1+\lambda_2}{2}$ (b) $\frac{2}{\lambda} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$
(c) $\lambda = \sqrt{\lambda_1\lambda_2}$ (d) $\frac{1}{\lambda^2} = \frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2}$ [08 April, 2019 (Shift-I)]

135. If the de-Broglie wavelength of an electron is equal to 10^{-3} times the wavelength of a photon of frequency 6×10^{14} Hz, then the speed of electron is equal to (Speed of light = 3×10^8 m/s ; Planck's constant = 6.63×10^{-34} Js; Mass of electron = 9.1×10^{-31} kg)
(a) 1.1×10^6 m/s (b) 1.7×10^6 m/s
(c) 1.8×10^6 m/s (d) 1.45×10^6 m/s [11 Jan, 2019 (Shift-I)]

136. A nucleus A, with a finite de-broglie wavelength λ_A, undergoes spontaneous fission into two nuclei B and C of equal mass. B flies in the same direction as that of A, while C flies in the opposite direction with a velocity equal to half of that of B. The de-Broglie wavelengths λ_B and λ_C of B and C are respectively: [08 April, 2019 (Shift-II)]
(a) $2\lambda_A, \lambda_A$ (b) $\lambda_A, 2\lambda_A$ (c) $\lambda_A, \frac{\lambda_A}{2}$ (d) $\frac{\lambda_A}{2}, \lambda_A$

@FAKE-CBSE-KORAL-LEBUNET

137. A particle A of mass 'm' and charge 'q' is accelerated by a potential difference of 50 V. Another particle B of mass '$4\,m$' and charge 'q' is accelerated by a potential difference of 2500 V. The ratio of de-Broglie wavelength $\frac{\lambda_A}{\lambda_B}$ is close to

[12 Jan, 2019 (Shift-I)]

(*a*) 10.00 (*b*) 0.07 (*c*) 14.14 (*d*) 4.47

138. In an electron microscope, the resolution that can be achieved is of the order of the wavelength of electrons used. To resolve a width of 7.5×10^{-12} m, the minimum electron energy required is close to:

[10 Jan, 2019 (Shift-I)]

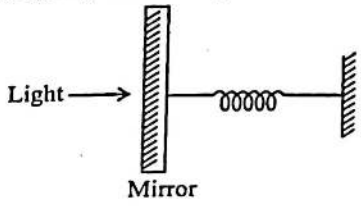
(*a*) 500 *KeV* (*b*) 100 *KeV* (*c*) 1 *KeV* (*d*) 25 *KeV*

139. A particle '*P*' is formed due to a completely inelastic collision of particles '*x*' and '*y*' having de-Broglie wavelengths 'λ_x' and 'λ_y' respectively. If *x* and *y* were moving in opposite directions, then the de-Broglie wavelength of '*P*' is **[09 April, 2019 (Shift-II)]**

(*a*) $\lambda_x + \lambda_y$ (*b*) $\frac{\lambda_x\lambda_y}{\lambda_x + \lambda_y}$ (*c*) $\frac{\lambda_x\lambda_y}{|\lambda_x - \lambda_y|}$ (*d*) $\lambda_x - \lambda_y$

140. A perfectly reflecting mirror of mass *M* mounted on a spring constitutes a spring-mass system of angular frequency Ω such that $\frac{4\pi M\Omega}{h} = 10^{24}\,m^{-2}$ with *h* as Planck's constant. N photons of wavelength $\lambda = 8\pi \times 10^{-6}$ m strike the mirror simultaneously at normal incidence such that the mirror gets displaced by 1 μm. If the value of *N* is $x \times 10^{12}$, then the value of *x* is_____.

[Consider the spring as massless] **[JEE Adv, 2019]**



JEE-Advanced

Energy of Photon

Single Correct

1. A photon collides with a stationary hydrogen atom in ground state inelastically. Energy of the colliding photon is 10.2 *eV*. After a time interval of the order of microsecond another photon collides with same hydrogen atom inelastically with an energy of 15 *eV*. What will be observed by the detector? **(IIT-JEE 2005)**

(*a*) 2 photons of energy 10.2 *eV*

(*b*) 2 photons of energy 1.4 *eV*

(*c*) One photon of energy 10.2 *eV* and an electron of energy 1.4 *eV*

(*d*) One photon of energy 10.2 *eV* and another photon of energy 1.4 *eV*

Multiple Correct

2. A free hydrogen atom after absorbing a photon of wavelength λ_a gets excited from the state n = 1 to the state n = 4. Immediately after that the electron jumps to n = m state by emitting a photon of wavelength λ_e. Let the change in momentum of atom due to the absorption and the emission are Δp_a and Δp_e, respectively. If $\frac{\lambda_a}{\lambda_e} = \frac{1}{5}$, which of the option(s) is/are correct?

[Use hc = 1242 eV nm; 1 nm = 10^{-9}m, h and c are Planck's constant and speed of light, respectively]

C-26.93 W-34.16 UA-30.82 PC-8.09 (JEE Adv. 2019)

(*a*) m = 2

(*b*) $\lambda_e = 418$ nm

(*c*) $\Delta p_a / \Delta p_e = \frac{1}{2}$

(*d*) The ratio of kinetic energy of the electron in the state n = m to the state n = 1 is 1/4

Match the Column

3. In the following, Column-I lists some physical quantities and the Column-II gives approximate energy values associated with some of them. Choose the appropriate value of energy from Column-II for each of the physical quantities in Column-I and write the corresponding letters *A*, *B*, *C* etc., against the number (*i*), (*ii*) and (*iii*) etc., of the physical quantity. **(IIT-JEE 1997)**

Column-I		Column-II	
(*i*)	Energy of thermal neutrons	(A)	0.025 eV
(*ii*)	Energy of X-ray	(B)	0.5eV
(*iii*)	Binding energy per nucleon	(C)	3eV
(*iv*)	Photoelectric threshold of a metal	(D)	20 eV
		(E)	8 MeV
		(F)	10 keV

Subjective

4. Two metallic plates *A* and *B* each of area $5 \times 10^{-4}\,m^2$, are placed parallel to each other at separation of 1 cm. Plate *B* carries a positive charge of 33.7×10^{-12} *C*. A monochromatic beam of light, with photons of energy 5*eV* each, starts falling on plate *A* at *t* = 0 so that 10^{16} photons fall on it per square meter per second. Assume that one photo-electron is emitted for every 10^6 incident photons. Also assume that all the emitted photoelectrons are collected by plate *B* and the work function of plate A remains constant at the value 2*eV* Determine **(IIT-JEE 2002)**

(*a*) the number of photoelectrons emitted up to *t* = 10*s*,

(*b*) the magnitude of the electric field between the plates *A* and *B* at *t* = 10*s* and

(*c*) the kinetic energy of the most energetic photoelectrons emitted at *t* = 10*s* when it reaches plate *B*.

Neglect the time taken by the photo-electron to reach plate *B*.

(Take $\varepsilon_0 = 8.85 \times 10^{-12} C^2/N - m^2$)

@FAKE_CBSE_OR_JEEDUNET

Photoelectric Effect

Single Correct

5. When light of a given wavelength is incident on a metallic surface, the minimum potential needed to stop the emitted photoelectrons is 6.0 V. This potential drops to 0.6 V if another source with wavelength four times that of the first one and intensity half of the first one is used. What are the wavelength of the first source and the work function of the metal, respectively? [Take $\frac{hc}{e} = 1.24 \times 10^{-6}$ J mC^{-1}.]

C-37.8 W-31.15 UA-31.05 (JEE Adv. 2022)

(a) 1.72×10^{-7} m, 1.20 eV (b) 1.72×10^{-7} m, 5.60 eV
(c) 3.78×10^{-7} m, 5.20 eV (d) 3.78×10^{-7} m, 1.20 eV

6. A photoelectric material having work-function ϕ_0 is illuminated with light of wavelength $\lambda\left(\lambda < \frac{hc}{\phi_0}\right)$. The fastest photo-electron has a de-Broglie wavelength λ_d. A change in wavelength of the incident light by $\Delta\lambda$ results in a change $\Delta\lambda_d$ in λ_d. Then, the ratio $\frac{\Delta\lambda_d}{\Delta\lambda}$ is proportional to

C-16.5 W-39.99 UA-43.51 (JEE Adv. 2017)

(a) $\frac{\lambda_d^2}{\lambda^2}$ (b) $\frac{\lambda_d}{\lambda}$ (c) $\frac{\lambda_d^3}{\lambda}$ (d) $\frac{\lambda_d^3}{\lambda^2}$

7. In a historical experiment to determine Planck's constant, a metal surface was irradiated with light of different wavelengths. The emitted photo-electron energies were measured by applying a stopping potential. The relevant data for the wavelength (λ) of incident light and the corresponding stopping potential (V_0) are given below:

C-53.68 W-28.39 UA-17.93 (JEE Adv. 2016)

$\lambda(\mu m)$	V_0 (Volt)
0.3	2.0
0.4	1.0
0.5	0.4

Given that $c = 3 \times 10^8\ ms^{-1}$ and $e = 1.6 \times 10^{-19}\ C$, Planck's constant (in units of $J - s$) found from such an experiment is)

(a) 6.0×10^{-34} (b) 6.4×10^{-34} (c) 6.6×10^{-34} (d) 6.8×10^{-34}

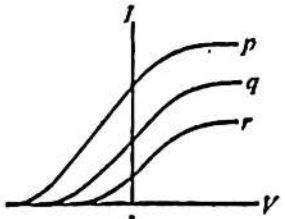
8. A metal surface is illuminated by light of two different wavelengths 248nm and 310nm. The maximum speeds of the photoelectrons corresponding to these wavelengths are u_1 and u_2, respectively. If the ratio $u_1 : u_2 = 2 : 1$ and $hc = 1240eVnm$, the work function of the metal is nearly

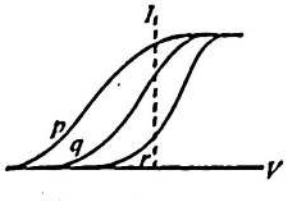
C-47.32 W-29.51 UA-23.17 (JEE Adv. 2014)

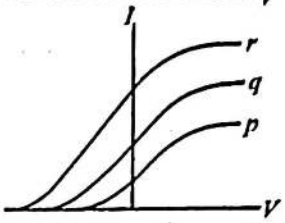
(a) 3.7eV (b) 3.2eV (c) 2.8eV (d) 2.5eV

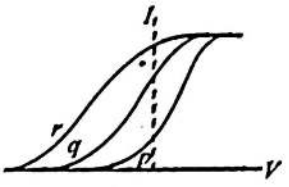
9. Photoelectric effect experiments are performed using three different metal plates p, q and r having work functions $\phi_p = 2.0eV$, $\phi_q = 2.5eV$ and $\phi_r = 3.0eV$, respectively. A light beam containing wavelengths of 550 nm, 450 nm and 350 nm with equal intensities illuminates each of the plates. The correct I-V graph for the experiment is

(IIT-JEE 2009)

(a) 

(b) 

(c) 

(d) 

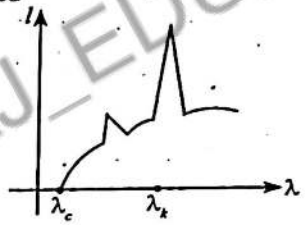
10. The potential difference applied to an X-ray tube is $5kV$ and the current through it is 3.2 mA. Then the number of electrons striking the target per second is

(IIT-JEE 2002)

(a) 2×10^{16} (b) 5×10^{6} (c) 1×10^{17} (d) 4×10^{15}

11. The intensity of X-rays from a coolidge tube is plotted against wavelength λ as shown in the figure. The minimum wavelength found is λ_c and the wavelength of the K_α line is λ_k. As the accelerating voltage is increased

(IIT-JEE 2001)



(a) $\lambda_k - \lambda_c$ increases (b) $\lambda_k - \lambda_c$ decreases
(c) λ_k increases (d) λ_k decreases

12. The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photo-electron emission from this substance is approximately

(IIT-JEE 1998)

(a) 540 nm (b) 400 nm (c) 310 nm (d) 220 nm

13. The maximum kinetic energy of photoelectrons emitted from a surface when photons of energy 6 eV fall on it is 4 eV. The stopping potential in volt is

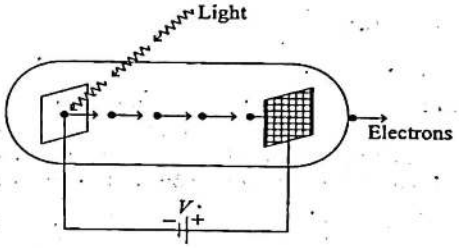
(IIT-JEE 1997)

(a) 2 (b) 4 (c) 6 (d) 10

Multiple Correct

14. Light of wavelength λ_{ph} falls on a cathode plate inside a vacuum tube as shown in the figure. The work function of the cathode surface is ϕ and the anode is a wire mesh of conducting material kept at a distance d from the cathode. A potential difference V is maintained between the electrodes. If the minimum de Broglie wavelength of the electrons passing through the anode is λ_e, which of the following statements(s) is/are true?

C-11.66 W-46.12 UA-42.21 PC-0 (JEE Adv. 2016)



@TAKE_CBSE_X @RAJ_EDUSET

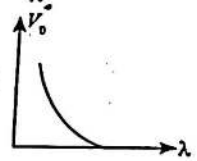
(a) λ_e increases at the same rate as λ_{ph} for $\lambda_{ph} < hc/\phi$

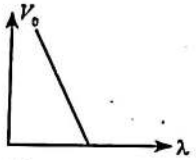
(b) λ_e is approximately halved, if d is doubled

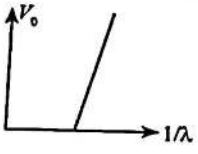
(c) λ_e decreases with increase in ϕ and λ_{ph}

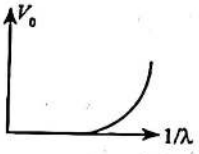
(d) For large potential difference ($V >> \phi/e$), λ_e is approximately halved if V is made four times.

15. For photo-electric effect with incident photon wavelength λ, the stopping potential is V_0. Identify the correct variation(s) of V_0 with λ and $\frac{1}{\lambda}$. **(JEE Adv. 2015)**

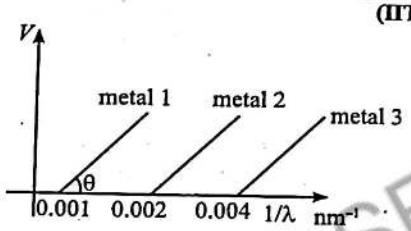
(a) 

(b) 

(c) 

(d) 

16. The graph between $1/\lambda$ and stopping potential (V) of three metals having work functions ϕ_1, ϕ_2 and ϕ_3 in an experiment of photoelectric effect is plotted as shown in the figure. Which of the following statement(s) is/are correct? (Here, λ is the wavelength of the incident ray). **(IIT-JEE 2006)**



(a) Ratio of work functions $\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 4$

(b) Ratio of work functions $\phi_1 : \phi_2 : \phi_3 = 4 : 2 : 1$

(c) tan θ is directly proportional to hc/e, where h is Planck's constant and c is the speed of light

(d) The violet colour light can eject photoelectrons from metals 2 and 3

17. When photons of energy 4.25 eV strike the surface of a metal A, the ejected photoelectrons have maximum kinetic energy T_A expressed in eV and de-Broglie wavelength λ_A. The maximum kinetic energy of photoelectrons liberated from another metal B by photons of energy 4.70 eV is $T_B = (T_A - 1.50 \text{ eV})$. If the de-Broglie wavelength of these photoelectrons is $\lambda_B = 2\lambda_A$, then **(IIT-JEE 1994)**

(a) the work function of A is 2.25 eV

(b) the work function of B is 4.20 eV

(c) $T_A = 2.00$ eV

(d) $T_B = 2.75$ eV

18. When a monochromatic point source of light is at a distance of 0.2 m from a photoelectric cell, the cut-off voltage and the saturation current are respectively 0.6 V and 18.0 mA. If the same source is placed 0.6 m away from the photoelectric cell, then **(IIT-JEE 1992)**

(a) the stopping potential will be 0.2 V

(b) the stopping potential will be 0.6 V

(c) the saturation current will be 6.0 mA

(d) the saturation current will be 2.0 mA

19. The threshold wavelength for photoelectric emission from a material is 5200 Å. Photoelectrons will be emitted when this material is illuminated with monochromatic radiation from a **(IIT-JEE 1982)**

(a) 50 W infrared lamp (b) 1 W infrared lamp

(c) 50 W ultraviolet lamp (d) 1 W ultraviolet lamp

Numerical Types/Integer Types

20. A Hydrogen-like atom has atomic number Z. Photons emitted in the electronic transitions from level $n = 4$ to level $n = 3$ in these atoms are used to perform photoelectric effect experiment on a target metal. The maximum kinetic energy of the photoelectrons generated is 1.95 eV. If the photoelectric threshold wavelength for the target metal is 310 nm, the value of Z is_____.

[Given: $hc = 1240$ eV-nm and $Rhc = 13.6$ eV, where R is the Rydberg constant, h is the Planck's constant and c is the speed of light in vacuum] **C-38.37 W-45.47 UA-16.16 (JEE Adv. 2023)**

21. In a photo-emission experiment, the maximum kinetic energies of photoelectrons from metals P, Q and R are E_P, E_Q and E_R, respectively, and they are related by $E_P = 2E_Q = 2E_R$. In this experiment, the same source of monochromatic light is used for metals P and Q while a different source of monochromatic light is used for the metal R. The work functions for metals P, Q and R are 4.0 eV, 4.5 eV and 5.5 eV, respectively. The energy of the incident photon used for metal R, in eV, is_____.

C-44.25 W-46.94 UA-8.8 (JEE Adv. 2021)

22. The work functions of silver and sodium are 4.6 and 2.3eV, respectively. The ratio of the slope of the stopping potential versus frequency plot for silver to that of sodium is

C-39.7 W-40.8 UA-19.5 (JEE Adv. 2013)

23. A silver sphere of radius 1 cm and work function 4.7 eV is suspended from an insulating thread in free-space. It is under continuous illumination of 200 nm wavelength light. As photoelectrons are emitted, the sphere gets charged and acquires a potential. The maximum number of photoelectrons emitted from the sphere is $A \times 10^Z$ (where $1 < A < 10$). The value of Z is **(IIT-JEE 2011)**

Fill in the Blanks

24. The maximum kinetic energy of electrons emitted in the photoelectric effect is linearly dependent on the ..... of the incident radiation. **(IIT-JEE 1984)**

True/False

25. In a photoelectric emission process, the maximum energy of the photoelectrons increases with increasing intensity of the incident light. **(IIT-JEE 1986)**

26. The kinetic energy of photoelectrons emitted by a photosensitive surface depends on the intensity of the incident radiation. **(IIT-JEE 1981)**

@FAKE-CBSE X @RU_EDUNET

Subjective

27. In a photoelectric experiment set-up, photons of energy 5 eV falls on the cathode having work function 3 eV.
   (a) If the saturation current is $i_A = 4\mu A$ for intensity 10^{-5} W/m², then plot a graph between anode potential and current.
   (b) Also, draw a graph for intensity of incident radiation 2×10^{-5} W/m².
   (IIT-JEE 2003)

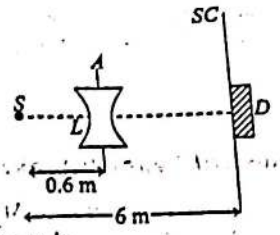
28. When a beam of 10.6 eV photons of intensity 2.0W/m² falls on a platinum surface of area 1.0×10^{-4}m² and work function 5.6 eV. 0.53% of the incident photons eject photoelectrons. Find the number of photoelectrons emitted per second and their minimum and maximum energies (in eV). Take 1 eV = 1.6×10^{-19} J.
   (IIT-JEE 2000)

29. Photoelectrons are emitted when 400 nm radiation is incident on a surface of work function 1.9 eV. These photoelectrons pass through a region containing α-particles. A maximum energy electron combines with an α-particle to form a He^+ ion, emitting a single photon in this process. He^+ ions thus formed are in their fourth excited state. Find the energies in eV of the photons lying in the 2 to 4 eV range, that are likely to be emitted during and after the combination.
   [Take $h = 4.14 \times 10^{-15}$ eV-s] **(IIT-JEE 1999)**

30. In a photoelectric effect set-up a point of light of power 3.2×10^{-3} W emits mono-energetic photons of energy 5.0 eV. The source is located at a distance of 0.8m from the centre of a stationary metallic sphere of work function 3.0 eV and of radius 8.0×10^{-3} m. The efficiency of photoelectrons emission is one for every 10^6 incident photons. Assume that the sphere is isolated and initially neutral and that photoelectrons are instantly swept away after emission.
   (IIT-JEE 1995)
   (a) Calculate the number of photoelectrons emitted per second.
   (b) Find the ratio of the wavelength of incident light to the de-Broglie wavelength of the fastest photoelectrons emitted.
   (c) It is observed that the photoelectrons emission stops at a certain time t after the light source is switched on why?
   (d) Evaluate the time t.

31. Light from a discharge tube containing hydrogen atoms falls on the surface of a piece of sodium. The kinetic energy of the fastest photoelectrons emitted from sodium is 0.73 eV. The work function for sodium is 1.82 eV. **(IIT-JEE 1992)**
   Find
   (a) the energy of the photons causing the photoelectrons emission.
   (b) the quantum numbers of the two levels involved in the emission of these photons.
   (c) the change in the angular momentum of the electron in the hydrogen atom, in the above transition, and
   (d) the recoil speed of the emitting atom assuming it to be at rest before the transition. (Ionization potential of hydrogen is 13.6 eV.)

32. A monochromatic point source S radiating wavelength 6000 Å, with power 2 W, an aperture A of diameter 0.1 m and a large screen SC are placed as shown in figure. A photo-emissive detector D of surface area 0.5 cm² is placed at the centre of the screen. The efficiency of the detector for the photo-electron generation per incident photon is 0.9. **(IIT-JEE 1991)**



   (a) Calculate the photon flux at (per unit area per unit time) the centre of the screen and the photo-current in the detector.
   (b) If the concave lens L of focal length 0.6 m is inserted in the aperture as shown, find the new values of photon flux and photo-current. Assume a uniform average transmission of 80% from the lens.
   (c) If the work function of the photo-emissive surface is 1eV, calculate the values of the stopping potential in the two cases (without and with the lens in the aperture).

33. Electrons in hydrogen-like atom (Z = 3) make transitions from the fifth to the fourth orbit and from the fourth to the third orbit. The resulting radiations are incident normally on a metal plate and eject photoelectrons. The stopping potential for the photoelectrons ejected by the shorter wavelength is 3.95 V. Calculate the work function of the metal, and the stopping potential for the photoelectrons ejected by the longer wavelength (Rydberg's constant = 1.094×10^7 m^{-1})
   (IIT-JEE 1990)

34. A beam of light has three wavelengths 4144Å, 4972Å and 6216Å with a total intensity of 3.6×10^{-3} Wm^{-2} equally distributed amongst the three wavelengths. The beam falls normally on an area 1.0 cm² of a clean-metallic surface of work function 2.3 eV. Assume that there is no loss of light by reflection and that each energetically capable photon ejects one electron. Calculate the number of photoelectrons liberated in two seconds. **(IIT-JEE 1989)**

De-Broglie Wavelength

Single Correct

35. Electrons with de-Broglie wavelength λ fall on the target in an X-ray tube. The cut-off wavelength of the emitted X-rays is
   (IIT-JEE 2007)
   (a) $\lambda_0 = \frac{2mc\lambda^2}{h}$ (b) $\lambda_0 = \frac{2h}{mc}$
   (c) $\lambda_0 = \frac{2m^2c^2\lambda^3}{h^2}$ (d) $\lambda_0 = \lambda$

36. The energy of a photon is equal to the kinetic energy of a proton. The energy of the photon is E. Let $\lambda_1 bc$ the de-Broglie wavelength of the proton and λ_2 be the wavelength of the photon. The ratio λ_1/λ_2 is proportional to . **(IIT-JEE 2004)**
   (a) E^0 (b) $E^{1/2}$ (c) E^{-1} (d) E^{-2}

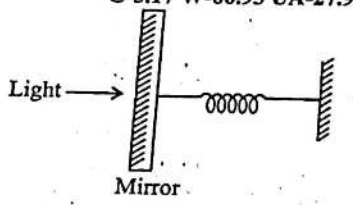
@FAKE_CBSE_YOGRAJ_BANSAL_NET

37. A particle of mass M at rest decays into two particles of masses m_1 and m_2 and having non-zero velocities. The ratio of the de-Broglie wavelengths of the particles λ_1/λ_2 is **(IIT-JEE 1999)**

(a) m_1/m_2 (b) m_2/m_1 (c) 1 (d) $\sqrt{m_2}/\sqrt{m_1}$

Numerical Types/Integer Types

38. A perfectly reflecting mirror of mass M mounted on a spring constitutes a spring-mass system of angular frequency Ω such that $\frac{4\pi M\Omega}{h} = 10^{24} m^{-2}$ with h as Planck's constant. N photons of wavelength $\lambda = 8\pi \times 10^{-6}$ m strike the mirror simultaneously at normal incidence such that the mirror gets displaced by 1 μm. If the value of N is $x \times 10^{12}$, then the value of x is_____. [Consider the spring as massless] **C-5.17 W-66.93 UA-27.9 (JEE Adv. 2019)**



39. A proton is fired from very far away towards a nucleus with charge $Q = 120\ e$, where e is the electronic charge. It makes a closest approach of 10 fm to the nucleus. The de-Broglie wavelength (in units of fm) of the proton at its start is [Take the proton mass, $m_p = (5/3) \times 10^{-27}$ kg; J–s/C; $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ m/f; 1 fm = 10^{-15} m]

C-11.45 W-70.78 UA-17.78 (IIT-JEE 2012)

40. An α-particle and a proton are accelerated from rest by a potential difference of 100 V. After this, their de-Broglie wavelengths are λ_α and λ_p respectively. The ratio $\frac{\lambda_p}{\lambda_\alpha}$, to the nearest integer, is

(IIT-JEE 2010)

Subjective

41. The potential energy of a particle varies as
$U(x) = E_0$ for $0 \le x \le 1$
$= 0$ for $x > 1$
For $0 \le x \le 1$, de-Broglie wavelength is λ_1 and for $x > 1$ the de-Broglie wavelength is λ_2. Total energy of the particle is $2E_0$. Find $\frac{\lambda_1}{\lambda_2}$. **(IIT-JEE 2005)**

42. An electron in a hydrogen like atom is in an excited state. It has a total energy of −3.4 eV. Calculate **(IIT-JEE 1996)**

(a) the kinetic energy,

(b) the de-Broglie wavelength of the electron.

@TAKE_CBSE_X @RAJ_EDUNET

ANSWER KEY

JEE-Main

1. (b)	2. (c)	3. (d)	4. (c)	5. (a)	6. (c)	7. (d)	8. [10]	9. (a)	10. (c)
11. (c)	12. (c)	13. (b)	14. (d)	15. (d)	16. (d)	17. (c)	18. (d)	19. (a)	20. (c)
21. (d)	22. (c)	23. (b)	24. (c)	25. (c)	26. (b)	27. (d)	28. (d)	29. (c)	30. (a)
31. (a)	32. (d)	33. (d)	34. (a)	35. (3)	36. (d)	37. (b)	38. (b)	39. (a)	40. (b)
41. (c)	42. (b)	43. (c)	44. (b)	45. [2]	46. [35]	47. (a)	48. (a)	49. (a)	50. (a)
51. (b)	52. (a)	53. (a)	54. (a)	55. (d)	56. (d)	57. [4]	58. [1]	59. (b)	60. (d)
61. (b)	62. (d)	63. (a)	64. (d)	65. [2]	66. [9]	67. [11]	68. (b)	69. (a)	70. (c)
71. (a)	72. (d)	73. (d)	74. (a)	75. (c)	76. (c)	77. [354]	78. (b)	79. (d)	80. (a)
81. (d)	82. (b)	83. (b)	84. (d)	85. (b)	86. (c)	87. (a)	88. (a)	89. (c)	90. (b)
91. (d)	92. (a)	93. (b)	94. (c)	95. (d)	96. (a)	97. (d)	98. (c)	99. (b)	100. (b)
101. (a)	102. (b)	103. (b)	104. (d)	105. (d)	106. (b)	107. [910]	108. (a)	109. (b)	110. (b)
111. (c)	112. (d)	113. (a)	114. (d)	115. (d)	116. (b)	117. (c)	118. (d)	119. (d)	120. (c)
121. (c)	122. (c)	123. (b)	124. (a)	125. (d)	126. (c)	127. (b)	128. (b)	129. (c)	130. (a)
131. (a)	132. (b)	133. (d)	134. (d)	135. (d)	136. (d)	137. (c)	138. (d)	139. (c)	140. [1]

JEE-Advanced

1. (d)	2. (a,d)	3. (i)-A; (ii)-F; (iii)-E; (iv)-C		5. (a)	6. (d)	7. (b)	8. (a)	9. (a)
10. (a)	11. (a)	12. (c)	13. (b)	14. (d)	15. (a,c)	16. (a,c)	17. (a,b,c)	18. (b,d)	19. (c,d)
20. [3]	21. [6]	22. [1]	23. [7]	25. [False]	26. [False]	35. (a)	36. (b)	37. (c)	38. [1]
39. [7]	40. [3]							

EXPLANATIONS

JEE-Main

1. (b)

2. (c) Radiation pressure $= \frac{I}{v}$

$= \frac{I \cdot \mu}{c} = \frac{6\times10^8 \times 3}{3\times10^8} = 6\ N/m^2$

3. (d) Given, P = 200 W

$\lambda_1 = 300$ nm

$\lambda_2 = 500$ nm

$n_1 \times \frac{hc}{\lambda_1} = 200$

$n_2 \times \frac{hc}{\lambda_2} = 200$

$\frac{n_1}{n_2} \times \frac{hc}{\lambda_2} = \frac{300}{500}$

$\frac{n_1}{n_2} = \frac{3}{5}$

4. (c) Photons and power are related as,

$P = nh\nu$

$$n = \frac{P}{h\nu} = \frac{2\times10^{-5}}{6.63\times10^{-34}\times6\times10^{14}}$$

$= 5 \times 10^{15}$

5. (a) Power (P) = V.I, therefore $I = \frac{P}{V}$

$\Rightarrow I = \frac{110}{220} = 0.5$ A

$I = \frac{n \cdot e}{t}$

$\Rightarrow 0.5 = \left(\frac{n}{t}\right)\left(1.6\times10^{-19}\right)$

$\Rightarrow \frac{n}{t} = \frac{0.5}{1.6\times10^{-19}} = 31.25 \times 10^{17}$

6. (c) Energy of one photon E

$= \frac{\text{Power}}{\text{Photon frequency}} = \frac{15\times10^3}{10^{16}}$

$\because E = h\nu$

$\Rightarrow \nu = \frac{15\times10^{-13}}{6\times10^{-34}} = 2.5\times10^{21}$

So the radiation belongs to gamma Rays.

7. (d) We know that, $\lambda = \frac{h}{mv}$

Therefore, two photons having equal linear momenta have equal wavelength. As wavelength decreases, momentum and energy of a photon increases.

8. [10] $\frac{hc}{\lambda} = \left(\frac{x}{3}h\right)c^2 [\because E_{photon} = mc^2]$

$\Rightarrow x = \frac{3}{\lambda c} = \frac{3}{10\times10^{-10}\times10^8} = 10$

9. (a) Power = Energy of photon × Number of photons emitted per sec

$P = n \times \frac{hc}{\lambda} \Rightarrow n \propto \lambda$

10. (c) $P = \frac{n.hc}{\lambda}$

$n = \frac{p\lambda}{h.c}$

$= \frac{2\times10^{-3}\times500\times10^{-9}}{6.6\times10^{-34}\times3\times10^8} = 5\times10^{15}$

11. (c)

12. (c)

13. (b) The longest wavelength of light that can cause the emission of photoelectrons from a substance is determined by the equation:

$\lambda_{max} = \frac{1240}{\text{Work function}}$

Given that the work function is 3.0 eV, we can substitute this value into the equation:

$\lambda_{max} = \frac{1240}{3.0} = 413.33$nm

So, the closest option is (b) 414 nm.

14. (d)

15. (d) Current will remain same.

As amount of energy incident on cell is same.

16. (d) There hold frequency $\nu_0 = \frac{\phi}{h}$

$\Rightarrow \phi_0 = h\nu_0$

$\Rightarrow 6.63 \times 1.6 \times 10^{-19} = 6.63 \times 10^{-34} \nu_0$

$\Rightarrow \nu_0 = \frac{1.6\times10^{-19}}{10^{-34}} \Rightarrow \nu_0 = 1.6 \times 10^{15}$ Hz

17. (c) Here stopping potential will remain same and saturation current corresponding to I_2 will be greater than that corresponding to I_1.

18. (d) Intensity of light $I = \frac{nh\nu}{A}$

$\therefore n = \frac{IA}{h\nu}$

At constant intensity, n decreases when frequency ν increases

$k_{max} = h\nu - \phi$

So on increasing ν, kinetic energy increases.

19. (a) Here, we have

$eV_0 = h\nu - \phi$

on dividing by e on both sides

$V_0 = \frac{h}{e}\nu - \frac{\phi}{e}$

M_2 material has higher work function, so statement-(II) is incorrect.

20. (c) Maximum kinetic energy

$= h\nu - \phi_0 = eV_s$

$V_s = \frac{h\nu}{e} - \frac{\phi_0}{e}$

21. (d) Given, $h\nu = 2.48$ eV

$V_s = 0.5$ V

$\because eV_s = h\nu - f$

$0.5\ V = 2.48 - \phi \Rightarrow \phi = 1.98$ V

22. (c) $e \cdot V_s = \frac{hc}{\lambda} - \phi$

$\Rightarrow eVs = \frac{1240}{300}eV - 2.13eV$

$\Rightarrow eVs. = 4.13eV - 2.13eV$

$\Rightarrow$ So, Vs = 2 volt

23. (b) $K\varepsilon_{max} = E_{photon} - \phi$

$\therefore 4.13 = 3.13 + K.E_{max}$

$\therefore K.E_{max} = 1\ eV$

24. (c)

A. Stopping potential depends on both frequency of light and work function.

B. Saturation current $\propto$ intensity of light

C. Maximum KE depends on frequency

D. Photoelectric effect is explained using particle theory

@TAKE_CBSE_X_GRAJ_EDUNET

25. (c) $eV_s = K_{max} = hf - \phi$

$V_s = \left(\frac{h}{e}\right)f + \left(\frac{-\phi}{e}\right)$

Slope of stopping potential is independent of nature of metal.

Hence,

$\text{slope}(V_s)_{Gold} = \text{slope}(V_s)_{Aluminium}$

26. (b) Formula of work function $\phi = \frac{hc}{\lambda}$

$\lambda_A = \left(\frac{1242}{9}\right) = 138 \text{ nm}$

$\lambda_B = \left(\frac{1242}{4.5}\right) = 276 \text{ nm}$

$\lambda_B - \lambda_A = 138 \text{ nm}$

27. (d) For photoelectrons emission $h\nu > \phi$

Given that, wavelength of radiation $\lambda = 350$ nm

$\therefore$ Energy of photon, $E = \frac{hc}{\lambda} = \frac{12400}{\lambda(\text{Å})}$

$\Rightarrow E = \frac{12400}{350 \times 10^{-9}} = \frac{12400}{3500 \text{ A}} = \frac{124}{35}$

$= 3.54$ eV

Since, $E < \phi_A$ and $E > \phi_B$

So, second plate will be able to emit electron.

28. (d) From the equation of photoelectric effect

$eV_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$

$\frac{eV_0}{4} = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0}$

Pluggin in the value of eV_0

$\Rightarrow \frac{1}{4}\left(\frac{hc}{\lambda} - \frac{hc}{\lambda_0}\right) = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0}$

$\Rightarrow \lambda_0 = 3\lambda$

29. (c) $eV_0 = h\nu - \phi$

$\therefore$ work function, $\phi = h\nu$

$= 6.6 \times 10^{-34} \times 5 \times 10^{14} = 33 \times 10^{-20}$ J

Stopping potential will be zero when incident and threshold frequencies are equal.

$\phi_{(eV)} = \frac{33 \times 10^{-20}}{1.6 \times 10^{-19}} = 2.07eV$

30. (a) UV rays are most effective for emission of electrons from a metallic surface because they have maximum frequency.

$KE_{max.} = h_\nu - h\nu_0$

31. (a) Intensity of light $\propto$ photo current

$KE_{max} = h\nu - \phi$

KE_{max} depends on frequency

32. (d) As the threshold wavelength is 5500Å, therefore for photoelectric emission wavelength of radiation,

$\lambda < 5500$Å

and wavelength of UV radiation,

$\lambda_{uv} < 5500$Å

$\therefore$ option (d) is correct

33. (d) Stopping potential $V_S = \frac{KE_{max}}{e}$ ...(i)

According to Einstein photo-electric equation

$E = \phi + KE_{max}$ ...(ii)

$\Rightarrow \frac{hc}{\lambda} - \phi = KE_{max}$

From eqn (i) and (ii)

It is clear that stopping potential does not depend on intensity or power of the light used, it only depends on the frequency or wavelength of the incident light.

So both statements I and II are correct

34. (a) $\because K_{max} = hf - hf_0$

For incident radiation having fequency $= 2f_0$

$\frac{1}{2}mv_1^2 = 2hf_0 - hf_0 = hf_0$

For incident radiation having fequency $= 5f_0$

$\frac{1}{2}mv_2^2 = 5hf_0 - hf_0 = 4hf_0$

$\Rightarrow \left(\frac{v_1}{v_2}\right) = \frac{1}{4} \Rightarrow \frac{v_1}{v_2} = \frac{1}{2}$

35. (3) From $\frac{1}{\lambda} = Rz^2\left[\frac{1}{3^2} - \frac{1}{4^2}\right]$

$= Rz^2\left(\frac{16-9}{9\times16}\right) = \frac{7}{9\times16}Rz^2$

$E = K_{max} + \phi = K_{max} + \frac{hc}{\lambda_0}$

$= 1.95 + \frac{1240}{310} = 1.95 + 4 = 5.95$ eV

$\frac{hc}{\lambda} = 5.95$ eV

$\frac{hc \times 7Rz^2}{9\times16} = 5.95$

$\therefore Z = 3$

36. (d) For maximum KE we need to take higher frequency $\left(f = \frac{9\times10^{15}}{2\pi} \text{ Hz}\right)$

$K_{max} = hf - \phi$

$= \frac{9\times10^{15} \times 4.14 \times 10^{-15}}{2\pi} - 2.50 \approx 3.43eV$

37. (b) Assertion A is correct: The photoelectric effect does not occur if the energy of the incident radiation is less than the work function of a metal. The work function is the minimum amount of energy required to remove an electron from the metal surface. If the energy of the incident radiation is lower than the work function, the photons do not possess enough energy to overcome the binding energy of the electrons, and no photoelectrons are emitted.

$h\nu = w_0 + K.E_{max}$

If $h\nu = w_0$

$\Rightarrow K.E_{max} = 0$

38. (b) $\frac{hc}{\lambda} - \phi = E$ ...(i)

$\frac{hc}{\lambda'} - \phi = 2E$ ...(ii)

Eqn (ii) – eqn (i) gives

$hc\left(\frac{1}{\lambda'} - \frac{1}{\lambda}\right) = E$

$\lambda' = \frac{hc\lambda}{E\lambda + hc}$

39. (a) $\text{K.E.} = \frac{hc}{\lambda} - \phi$

As radius, $r = \frac{mv}{eB} = \frac{\sqrt{2\,(K.E)m}}{eB}$

$\Rightarrow (reB)^2 = 2\text{m}\,(K.E)$

$\Rightarrow K.E = \frac{e^2B^2r^2}{2m}$

$= \frac{\left(1.6\times^{-19} \times 2\times10^{-3}2\times10^{-3}\right)^2}{2\times9.1\times10^{-31}}$

$= 2.25 \times 10^{-19}$ J

$= \frac{2.25\times10^{-19}}{1.6\times10^{-19}}eV = 1.40eV$

Work function,

$\phi = \frac{hc}{\lambda} - \text{K.E.}$

$= \frac{12400}{4500} - 1.40 = 1.36\,eV$

40. (b) According to the question,

$K_1 = \frac{hc}{\lambda_1} - \phi_0 = \frac{hc}{3\lambda_2} - \phi_0$ ...(i)

[Given, $\lambda_1 = 3\lambda_2$]

$K_2 = \frac{hc}{\lambda_2} - \phi_0$ ...(ii)

From (i) and (ii)

$K_2 - K_1 =$

@FAKE_CBSE_X @RAJ_ERUNET

$\therefore K_2 - K_1 = \frac{2}{3}K_2 + \frac{2}{3}\phi_0$

$\Rightarrow K_1 = \frac{K_2}{3} - \frac{2}{3}\phi_0$

$\therefore K_1 < \frac{K_2}{3}$

41. *(c)* Einstein's equation of photo-electric current

$K.E = \frac{hc}{\lambda} - \phi$

$\therefore K \cdot E_1 = \frac{1230}{800} - \phi$ ...(i)

$K \cdot E_2 = 2K \cdot E_1 = \frac{1230}{500} - \phi$ ...(ii)

From (i) & (ii)

$2 \times \frac{1230}{800} - 2\phi = \frac{1230}{500} - \phi$

$\Rightarrow \phi = 0.615\ eV$

42. *(b)* From Einstein-Photoelectric effect,

$\frac{1}{2}mV_{max}^2 = hf - \phi_0$

Photoelectric effect can be explained by particle nature of light. Threshold wavelengths is maximum wavelength at which emission takes place.

43. *(c)* $E_1 = 5\phi - \phi = 4\phi = \frac{1}{2}mv_1^2$

$E_2 = 10\phi - \phi = \frac{1}{2}mv_2^2$

$\Rightarrow \frac{V_1}{V_2} = \frac{\sqrt{\frac{8\phi}{m}}}{\sqrt{\frac{18\phi}{m}}}\sqrt{\frac{8}{18}} = \frac{\sqrt{4}}{9} = \frac{2}{3}$

44. *(b)* $KE_1 = h\upsilon_1 - \phi_0$

$\frac{1}{2}mv_1^2 = 3.8 - 0.6 = 3.2eV$ ...(i)

Similarly,

$KE_2 = h\upsilon_2 - \phi_0$

$\frac{1}{2}mv_2^2 = 1.4 - 0.6 = 0.8eV$ ...(ii)

On dividing equation (i) with equation (ii)

$\left(\frac{v_1}{v_2}\right)^2 = 4 \Rightarrow \frac{v_1}{v_2} = 2:1$

45. [2] $h\nu = h\nu_{th} + \frac{1}{2}mv_1^2$

For $\nu = 2\nu_{th}$

$\frac{1}{2}mv_1^2 = h\nu_{th}$ ...(i)

For $\nu = 5\nu_{th}$

$5h\nu_{th} = h\nu_{th} + \frac{1}{2}mv_2^2 \Rightarrow \frac{1}{2}mv_2^2 = 4h\nu_{th}$ ...(ii)

$\therefore \frac{\frac{1}{2}mv_1^2}{\frac{1}{2}mv_2^2} = \frac{h\nu_{th}}{4h\nu_{th}}$

$\left(\frac{v_1}{v_2}\right)^2 = \frac{1}{4} \Rightarrow v_1 = 2v_1$

46. [35] $eV_0 = \frac{hc}{\lambda} - h\nu_0$

$\Rightarrow 6.63\times10^{-34}\nu_0 = \frac{6.63\times10^{-34}\times3\times10^8}{6630\times10^{-10}} - 1.6\times10^{-19}\times0.42$

$\Rightarrow \nu_0 = 0.35\times10^{15} = 35\times10^{13}\ s^{-1}$

47. *(a)* $h\nu - \phi = 6eV$

$\frac{hc}{\lambda} - \phi = 6eV$ ...(i)

and $\frac{hc}{4\lambda} - \phi = 0.6eV$ ...(ii)

(i) − (ii)

$\frac{3hc}{4\lambda} = 5.4eV$

$\therefore \lambda = \frac{3hc}{4\times5.4eV} = \frac{3\times1.24\times10^{-6}}{4\times5.4}$

$= 1.72\times10^{-7}$ m

from equation (i)

$\frac{hc}{1.72\times10^{-7}} \times \frac{1}{1.6\times10^{-19}} - \phi = 6eV$

$\frac{2\times10^{-25}}{2.75\times10^{-26}} - \phi = 6$

$\Rightarrow \phi = (7.27 - 6) \cong 1.2eV$

48. *(a)* We know that,

$\frac{hc}{\lambda} = \phi e v_s$

$\therefore \frac{1240}{491} = \phi + 0.71$ ...(i)

$\frac{1240}{\lambda} = \phi + 1.43$ ...(ii)

Using above two equation we can calculate:

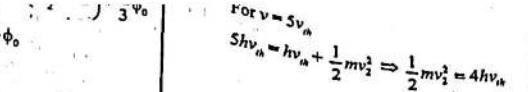
$\lambda = 382nm$

49. *(a)* $\frac{1}{2}mv_1^2 = hf_2 - \phi$

$\frac{1}{2}mv_2^2 = hf_2 - \phi$

$v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$

50. *(a)* $h\nu = 3.4 - 1.51 = 1.89$ eV



As we know that radius of circular path in magnetic field is given as

$r = \sqrt{\frac{2mK}{qB}} \Rightarrow K = \frac{r^2q^2B^2}{2m}$

$\Rightarrow K = \frac{(7\times10^{-3})^2\times(1.6\times10^{-19})\times(5\times10^{-4})^2}{2\times9.1\times10^{-31}}eV$

$= 107.7\times10^{-2}$ eV $= 1.08$ eV

$\Rightarrow \phi = h\nu - K = 1.89 - 1.08 = 0.81eV$

51. *(b)* We know that, $KE \propto V(nu)$

And, Intensity α number of photons.

52. *(a)* The stopping potential depends on frequency of incident electromagnetic radiation.

53. *(a)* We have given the energy of electron $= 3eV$

In 2nd excited state,

$E = -\frac{(13.6)}{9} = -1.51eV$

Energy of photon, $\frac{hc}{\lambda} = 4.512eV$

$KE_{max} = 4.512 - \frac{12400eV\text{Å}}{4000\text{Å}} = 1.41eV$

54. *(a)* $\lambda_1 = 280$ nm, $\lambda_2 = 400$ nm, $\phi = 2.5\ eV$.

$\frac{hc}{\lambda_1} = \phi + eV_1$

$hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = e(V_1 - V_2)$

$V_1 - V_2 = \frac{hc}{e}\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$

$= 12400\left(\frac{1}{2800} - \frac{1}{4000}\right)$

$\left[\lambda_1 \text{ and } \lambda_2 \text{ are taken in } A^\circ\right]$

$= 4.4 - 3.1 = 1.3V$

55. *(d)* $eV_{01} = \frac{hc}{\lambda_1} - \phi$

$eV_{02} = \frac{hc}{\lambda_2} - \phi$

$eV_{02} - eV_{01} = \frac{hc}{\lambda_2} - \frac{hc}{\lambda_1}$

$\Rightarrow V_{02} = V_{01} + \frac{hc}{e}\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right)$

@FAKE_CBSE_@RAJ_EBUNET

$\Rightarrow V_{02} = 0.48 + 12.43 \times 10^{-7} \times \left(\frac{1}{474.6} - \frac{1}{670.5}\right) \times 10^{-9}$

$= 1.25V$

56. (*d*) Given, $V_{s_1} = 4.8V, \lambda_1 = \lambda$

$V_{s_2} = 1.6\ V, \lambda_2 = 2\lambda$

By Einstein's equation of photoelectric effect,

$$\frac{hc}{\lambda} = \frac{hc}{\lambda_0} eV_s + \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

$$e \times 4.8 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0} \quad \ldots (i)$$

$$e \times 1.6 = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0} \quad \ldots (ii)$$

By dividing (i) by (ii)

$$\frac{hc\left(\frac{\lambda_0 - \lambda}{\lambda_0 \cdot \lambda}\right)}{hd\left(\frac{\lambda_0 - 2\lambda}{2\lambda_0 \cdot \lambda}\right)} = 3$$

$$\frac{2(\lambda_0 - \lambda)}{(\lambda_0 - 2\lambda)} = 3$$

$$2\lambda_0 - 2\lambda = 3\lambda_0 - 6\lambda \Rightarrow \lambda_0 = 4\lambda$$

57. [4] Let the work function of metal is W_0

$$K_1 = 3V_0 e = \frac{hc}{\lambda} - W_0 \quad \ldots(i)$$

$$K_2 = V_0 e = \frac{hc}{2\lambda} - W_0 \quad \ldots(ii)$$

On solving (*i*) and (*ii*), we get

$$\Rightarrow W_0 = \frac{hc}{4\lambda}$$

The threshold wavelength $= \frac{hc}{W_0} = 4\lambda$

58. [1] We know that, $E - \phi = \frac{1}{2}mv^2$

When $E = 2\phi, v = v_1$

$$2\phi - \phi = \frac{1}{2}mv_1^2 \quad \ldots (i)$$

When $E = 10\phi, v = v_2$

$$10\phi - \phi = \frac{1}{2}mv_2^2 \quad \ldots(ii)$$

Using equation (*i*) and (*ii*)

$$\Rightarrow \frac{1}{9} = \frac{v_1^2}{v_2^2} \Rightarrow v_1 : v_2 = 1:3$$

$$\Rightarrow x = 1$$

59. (*b*) K.E. of emitted photo electron,

$$KE = \frac{hc}{\lambda} - \phi \quad \ldots(i)$$

$\therefore$ At $\lambda_1 = 500$ nm

$$KE_1 = \frac{hc}{\lambda_1} - \phi \quad \ldots(ii)$$

At $\lambda_2 = 200$ nm

$$KE_2 = \frac{hc}{\lambda_2} - \phi = 3K_1 \text{ (Given)}$$

$$= 3\left(\frac{hc}{\lambda_1} - \phi\right) \Rightarrow \frac{hc}{1}\left(\frac{3}{\lambda_1} - \frac{1}{\lambda_2}\right) = 2\phi$$

$$\Rightarrow \phi = \frac{hc}{2}\left(\frac{3}{\lambda_1} - \frac{3}{\lambda_2}\right)$$

$$= \frac{hc}{2 \times 100nm}\left(\frac{3}{5} - \frac{1}{2}\right)$$

$$= \frac{1240}{2 \times 100}\frac{1}{10} = 0.62eV.$$

60. (*d*) $KE_{max} = E - \phi$

$$\Rightarrow K.E_{max} = \frac{12400}{\lambda(\text{in Å})} - \phi \text{ (in } eV)$$

$$\therefore \ r = \frac{\sqrt{2mKE}}{eB}$$

$$KE_{max} = \frac{r^2e^2B^2}{2m} \text{ (in J)}$$

$$= \frac{r^2eB^2}{2m} \text{ (in eV)}$$

$$\therefore \ \phi = \frac{12400}{6561} - \frac{r^2eB^2}{2m} = 1.1\,eV$$

61. (*b*) $V = \frac{h}{e}f - \frac{\phi}{e}$

Minimum energy for ejection = work function

$\phi = hf$ (for $v = 0$)

$$= \frac{6.62 \times 10^{-34} \times 5.5 \times 10^{14}}{1.6 \times 10^{-19}}$$

$= 2.27$ eV

62. (*d*) Here we have, $eV_{stop} = \frac{hc}{\lambda} - \phi$

Slope of curve, $\tan\theta = \frac{hc}{e} = \text{constant}$

As intensity of incident radiation is increased, there will be no change in the graph.

63. (*a*) Relation between K.E. De-Broglie wavelength and is

$$\lambda = \frac{h}{\sqrt{2}(\text{KE})m_e} \Rightarrow \lambda \propto \frac{1}{\sqrt{\text{KE}}}$$

$$\frac{\lambda_A}{\lambda_B} = \frac{\sqrt{kE_B}}{\sqrt{kE_A}} \Rightarrow \frac{1}{2} = \sqrt{\frac{T_A - 1.5}{T_A}}$$

$\Rightarrow T_A = 2$eV

$\therefore$ $KE_B = 2 - 1.5 = 0.5$ eV

Thus, $\phi_B = 4.5 - 0.5 = 4$ eV

64. (*d*) On increasing the biasing voltage of a photodiode the magnitude of procurement first increases and then attains a saturation.

65. [2] $\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi$

$$\frac{1}{2}mv_1^2 = 4 - \phi \quad \ldots(i)$$

$$\frac{1}{2}mv_2^2 = 2.5 - \phi \quad \ldots(ii)$$

Given $\frac{v_1}{v_2} = 2$

$$\Rightarrow 4 = \frac{4 - \phi}{2.5 - \phi} \Rightarrow \phi = 2eV$$

66. [9] $\frac{hc}{\lambda} = \phi + eV \quad \ldots(1)$

$$\frac{hc}{3\lambda} = \phi + \frac{eV}{4} \quad \ldots(2)$$

On subtracting (2) form (1)

$$\frac{hc}{\lambda}\left(1 - \frac{1}{3}\right) = \frac{3}{4}\text{eV} \Rightarrow \frac{hc}{\lambda}\frac{2}{3} = \frac{3}{4}\text{eV}$$

Now, $eV = \frac{8}{9}\frac{hc}{\lambda}$

$$\frac{hc}{\lambda} = \phi + \frac{8}{9}\frac{hc}{\lambda}$$ [Putting value of eV in eq (i) we get]

$$\phi = \frac{hc}{9\lambda} = \frac{hc}{\lambda_{th}}$$

$\lambda_{th} = 9\lambda \quad \therefore n = 9$

Hence, value of n is 9

67. [11] Energy of photon,

$$E = \frac{hc}{\lambda} = \frac{1240}{310} = 4eV > 2eV$$

(Hence photoelectric effect will take place)

$= 4 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-19}$ Joule

Number of photons incident per second

$$n = \frac{IA}{E} = \frac{6.4 \cdot 10^{-5} \cdot 1}{6.4 \cdot 10^{-19}} = 10^{14}$$

As, I out of every 1000 photons are responsible in ejecting 1 photoelectron

Therefore,number of photoelectron emitted per second $= \frac{10^{14}}{10^3} = 10^{11}$

@FAKE_CBSE_X @RAJ EDUNET

68. (b) $eV_0 = h\nu - \phi$

$V_0 = \frac{h\nu - \phi}{e}$

When $\nu = 4 \times 10^{14}\ Hz \Rightarrow V_0 = 0\ V$

$\therefore \phi = h\nu = \frac{6.63\times10^{-34}\times4\times10^{14}}{1.6\times10^{-19}} eV$

$\phi = 1.66\ eV$

69. (a) $\omega = 6 \times 10^{14} \times 2\pi$; $f = 6 \times 10^{14}$

$\lambda = \frac{C}{f} = \frac{3\times10^{14}}{6\times10^{14}} = 5000\text{Å}$

energy of photon $= \frac{12375}{5000} = 2.475\ eV$

$KE_{max} = E - \phi$

$eV_s = E - \phi$

$eV_s = 2.475 - 2$

$eV_s = 0.475$ eV

$V_s = 0.475\ V = 0.48$ volt

70. (c) Number of protons incident/unit time,

$= \frac{n}{t} = \frac{IA}{E} = \frac{16\times10^{-3}\times10^{-4}}{10\times1.6\times10^{-19}} = 10^{12}$

$\therefore$ Number of emitted photo electrons

$= \frac{10}{100}\times10^{12} = 10^{11}$

$(K.E.)_{max} = (10 - 5)\ eV = 5\ eV$

71. (a) $\frac{1240}{350} - \phi = (KE)_I = 4x$ ....(i)

$\frac{1240}{540} - \phi = (KE)_{II} = x$ ...(ii)

Equation (i) – Equation (ii)

$\frac{1240}{350} - \frac{1240}{540} = 3.542 - 2.296 = 3x$

$\Rightarrow 1.246 = 3x \Rightarrow x = 0.41$

$\therefore \phi = 2.296 - 0.41 = 1.886$

72. (d) $\frac{h\nu}{2} = \phi + V_0 e$ ...(i)

$\frac{h\nu}{2} = \phi + V_0 e$ ...(ii)

Using equation (i) – (ii)

$\frac{h\nu}{2} = -\frac{V_0 e}{2} \Rightarrow e = \frac{-h\nu}{V_0}$

So, $\phi = \frac{3h\nu}{2}$ $\therefore V_0 = \frac{3\nu}{2}$

73. (d) The maximum kinetic energy of the photoelectrons,

$KE_{max} = h\nu_{max} - \phi$

[Here ϕ, is work function]

$\frac{(6.6\times10^{-34})(6.28\times10^{7})(3\times10^{8})}{1.6\times10^{-19}\times2\times3.14} - 4.7$

$= 12.37 - 4.7 = 7.67\ eV$

74. (a) $K_{max} = hc\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)$

$K_{max} = (1237)\left(\frac{380-260}{280\times260}\right) = 1.5\ eV$

75. (c) If ϕ is the work function

$\frac{hc}{\lambda_1} = \phi + eV_1$ ...(I)

$\frac{hc}{\lambda_2} = \phi + eV_2$ ...(II)

Now equation (i)–equation (ii)

$hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = e(V_1 - V_2)$

$\therefore V_1 - V_2 = \frac{1240\times100}{300\times400} = 1.03V = 1V$

76. (c) Energy flux,

$I = 25\frac{W}{cm^2} = 25\times10^4\ W/m^2$

$P = 25 \times 25;\ W = 625\ W$

$\frac{hc}{\lambda}\frac{dn}{dt} = P$

$F = \frac{h}{\lambda}\frac{dn}{dt} = \frac{P}{c} = \frac{625}{3\times10^8}$

Momentum $= \frac{625\times40\times60}{3\times10^8} = 5\times10^{-3}\ Ns$

Hence, option (c) is correct answer.

77. [354] Radiation pressure $P = \frac{21}{C}$

Intensity, $I = \frac{1}{2}\epsilon_0 E_0^2 C$

$\therefore p = \frac{2}{C}\left(\frac{1}{2}\varepsilon_0 E_0^2 C\right)$

$= \varepsilon_0 E_0^2$

$= (8.85 \times 10^{-12}) \times (200)^2$

$= 354 \times 10^{-9}\ N/m^2$

78. (b) de-Broglie wavelength for photon

$E_P = \frac{hc}{\lambda_p} \Rightarrow \lambda_p = \frac{hc}{E_p}$

de-Broglie wavelength for electron

$\lambda_e = \frac{h}{m_e v_e} = \frac{h\nu_e}{2K_e}$

Given $v_e = 0.25\ c$

$\lambda_e = \frac{h\times0.25\,c}{2K_e} = \frac{hc}{8K_e}$

The de-Broglie wavelength of an electron is the same as that of a photon

$\lambda_p = \lambda_e$

$\frac{hc}{E_p} = \frac{hc}{8K_e}$

$\frac{K_e}{E_p} = \frac{1}{8}$

79. (d) As, De broglie wavelength

$\lambda = \frac{h}{p} = \frac{h}{mv} \Rightarrow v = \frac{h}{m\lambda}$

$\therefore \frac{v_p}{v_\alpha} = \frac{m_\alpha}{m_p}\times\frac{\lambda_\alpha}{\lambda_p}$

$= 4 \times 2 = 8$

80. (a) wavelenght is same for both proton and electron

$P = \frac{h}{\lambda}$ same for both

$P = \sqrt{2mK}$

Hence, $K \propto \frac{1}{m}$

$\Rightarrow \frac{KE_p}{KE_e} = \frac{m_e}{m_p} = \frac{1}{1836}$

81. (d) De Broglie wavelength of proton & electron = λ

$\because \lambda = \frac{h}{p}$ [Here h is planck's constant and p is momentum]

$\therefore P_{proton} = P_{electron}$

$\because KE = \frac{p^2}{2m}$

$KE_{proton} < KE_{electron}$

$[K_p < K_e]$

82. (b) De- Broglie wavelength,

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mk}}$

$\Rightarrow \lambda_{DB} \propto \frac{1}{\sqrt{m}}$

$\Rightarrow \lambda_a < \lambda_p < \lambda_e$

83. (b) Wavelength of the particle,

$\lambda = \frac{h}{\sqrt{2mE}}$ or $E = h\nu$

$[ML^2T^{-2}] = h[T^{-1}]$

$h = [ML^2T^{-1}]$

84. (d) $\therefore \lambda = \frac{h}{\sqrt{2meV}}$

$\therefore \lambda \propto \frac{1}{\sqrt{V}} \Rightarrow \frac{\lambda}{\lambda_0} = \sqrt{\frac{20}{40}}$

$\Rightarrow \lambda = \frac{\lambda_0}{\sqrt{2}}$

85. (b) de-broglie wavelength is given by

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$

@FAKE_CBSE_GURAJ_EDUNET

$\therefore \lambda \propto \frac{1}{\sqrt{m}}$

$\because m_\alpha > m_p > m_e$

$\Rightarrow \lambda_e > \lambda_p > \lambda_\alpha$

86. (c) $\because \lambda = \frac{h}{\sqrt{2mqV}} \Rightarrow \frac{\lambda_\alpha}{\lambda_p} = \frac{h}{\sqrt{2m_\alpha q_\alpha V}} \times \frac{\sqrt{2m_p q_p V}}{h}$

$\Rightarrow m = 8$

87. (a)

From K.T.G.

$v_{RMS} = \sqrt{\frac{3k_B T}{m}} \Rightarrow v_{RMS} \propto \sqrt{T}$

$\lambda = \frac{h}{mv_{RMS}} \Rightarrow \lambda \propto \frac{1}{V_{RMS}}$

$\therefore \lambda = \frac{1}{\sqrt{T}}$

$\Rightarrow \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{300}{600}} = \frac{1}{\sqrt{2}}$

$\lambda_2 = \frac{\lambda_1}{\sqrt{2}}$

88. (a) $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mq\Delta V}}$

$\left(\because p = \sqrt{2mE} \text{ and } E = q\Delta v\right)$

$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha V_\alpha q_\alpha}{m_p V_p q_p}}$

$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{4\times4\times2}{1\times2\times1}} = \frac{4}{1}$

$\Rightarrow \lambda_p : \lambda_\alpha = 4:1$

89. (c) From deBroglie, $\lambda = \frac{h}{p}$

$\lambda = \frac{h}{\sqrt{2mE}} \quad (\because p = \sqrt{2mE})$

$\lambda' = \frac{h}{\sqrt{2\,m\left(\frac{E}{4}\right)}} = \frac{2\,h}{\sqrt{2mE}} = 2\lambda$

90. (b) $KE = \frac{p^2}{2m} = \frac{h^2}{2ml^2}$

$\Rightarrow KE\ \mu\ \frac{1}{m}$

$\Rightarrow \frac{KE_p}{KE_a} = \frac{m_a}{m_p} = 4:1$

91. (d) Conceptual

92. (a) $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$ since, E is constant

$\therefore \lambda \propto \frac{1}{\sqrt{m}} \Rightarrow \frac{\lambda_p}{\lambda_e} = \sqrt{\frac{m_e}{m_p}} = \sqrt{\frac{1}{184g}} = 1:43$

93. (b) $\because KE = \frac{P^2}{2m}$ and $P = \frac{h}{\lambda}$

$\Rightarrow eV_1 = \frac{\left(\frac{h}{\lambda}\right)^2}{2m}$ ...(i)

$\Rightarrow eV_2 = \frac{\left(\frac{h}{1.5\lambda}\right)^2}{2m}$ ...(ii)

$\Rightarrow \frac{V_1}{V_2} = (1.5)^2 = \frac{9}{4}$

94. (c) de - Broglie wavelength

$\lambda = \frac{h}{\sqrt{2mK}}$

$\because$ Mass, $M_e = \frac{m}{1840}, m_\alpha = 4m, m_p = m$

Kinetic energy, $K_e = 4K, K_\alpha = 2K, K_p = K$

Charge, $q_e = e, q_\alpha = 2e, q_p = e$

$\therefore \lambda_\alpha < \lambda_p < \lambda_e$

95. (d) DeBroglie wavelength is $\lambda = \frac{h}{p} = \frac{h}{mv}$

As $\lambda_p = \lambda_e$

$\Rightarrow m_p v_p = m_e v_e$

$\Rightarrow p_p = p_e$

$\frac{p_p}{p_e} = \frac{1}{1}$

96. (a) For electron $\lambda_e = \frac{h}{P_e} = \frac{h}{\sqrt{2m_e K_e}}$

$\Rightarrow \lambda_e^2 = \frac{h^2}{2m_e k_e} \Rightarrow K_e = \frac{h^2}{2m_e\lambda_e^2}$ ...(i)

For photon $K_P = \frac{hc}{\lambda_P}$ ...(ii)

According to question.

$K_e = K_P$

$\frac{h^2}{2m_e\lambda_e^2} = \frac{hc}{\lambda_p}$

$\lambda_p \propto \lambda_e^2$

97. (d) From de-Broglie hypothesis

$l = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$

$\Rightarrow \frac{\lambda_P}{\lambda_D} = \frac{\sqrt{2m_D eV_D}}{\sqrt{2m_P eV_P}} = \frac{1}{\sqrt{2}}$

$\Rightarrow \frac{2m_P V_D}{m_P V_P} = \frac{1}{2} \Rightarrow \frac{V_P}{V_D} = 4:1$

$\Rightarrow \frac{2m_P V_D}{m_P V_P} = \frac{1}{2} \Rightarrow \frac{V_P}{V_D} = 4:1 \ (\because m_D = 2m_p)$

98. (c) Let $M_1 = \frac{M'}{3}$ and $M_2 = \frac{2M'}{3}$

Applying the law of conservation of linear momentum.

$M_1V_1 + M_2V_2 = 0$

$\Rightarrow M_1V_1 = -M_2V_2$

And, De-Broglie wave length, $\lambda = \frac{h}{MV}$

$\therefore \left|\frac{\lambda_1}{\lambda_2}\right| = \left|\frac{M_2V_2}{M_1V_1}\right| = 1$

99. (b) $k_\alpha = 2eV \Rightarrow P_\alpha = \sqrt{2K_\alpha m_\alpha}$

$k_P = eV \Rightarrow P_P = \sqrt{2K_P m_P}$

$\therefore \frac{P_\alpha}{P_P} = \sqrt{\frac{2\times(4m_P)}{m_P}} = \sqrt{8}:1 = 2\sqrt{2}:1$

100. (b) $\lambda = \frac{h}{P} = \frac{h}{\sqrt{2m(K.E)}}$

$\because$ K.E. = Constant

$\therefore \lambda \propto \frac{1}{\sqrt{m}}$

$\Rightarrow \frac{\lambda_\alpha}{\lambda_{C_{12}}} = \sqrt{\frac{m_{C_{12}}}{m_\alpha}} = \sqrt{\frac{12}{4}} = \sqrt{3}:1$

101. (a) Davission – Germer demonstrated that electron beam can undergo diffraction when passed through atomic structure which confirm the wave nature of electron.

102. (b) $\lambda = \frac{h}{\sqrt{2Em}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$

$\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$

103. (b) $\lambda_e = \frac{h}{mv} = \frac{h}{p_e}$ ...(i)

$\lambda_{Ph} = \frac{h}{p_{Ph}}$ ...(ii)

According to the $\lambda e = \lambda Ph$

$\Rightarrow \frac{p_e}{p_{Ph}} = 1$ ...(iii)

$\therefore \frac{KE_e}{KE_{ph}} = \frac{\frac{1}{2}p_e v}{p_{ph}c}\left[\because KE = \frac{1}{2}pv, E_{ph} = p_{ph}c\right]$

$\therefore \frac{E_e}{E_{ph}} = \frac{v}{2c}$

@TAKE_CBSE_X @RAJ_EDUNET

104. (d) Given that $\vec{v} = v_0\hat{i}$ and $\vec{E} = -E_0\hat{i}$
Acceleration of e in the magnetic field,

$$a = \frac{F}{m} = \frac{eE_0}{m}$$

$$\therefore \vec{v} = v_0 + \frac{eE_0 t}{m}\hat{i}$$

So, de Broglie wave length, $\lambda = \frac{h}{mv}$

$$\Rightarrow \lambda = \frac{h}{mv_0\left(1+\frac{eE_0}{mv_0}t\right)} = \frac{\lambda_0}{\left(1+\frac{eE_0}{mv_0}t\right)}$$

105. (d) As, $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mqV}}$

Put m, q for an electron, we get

$$\lambda = \frac{1.22}{\sqrt{V}}nm$$

On comparing to $\lambda = \frac{1.227}{x}$, we get

$$x = \sqrt{V}$$

106. (b) Given, $V = 1.24 \times 10^6$ volt
We know that,

$$\lambda_{min} = \frac{hc}{eV} = \frac{1242\,nm}{e\left(1.24\times10^6\right)}$$

[Since, hc = 1242 nm]

$$\lambda_{min} = \frac{1000\times10^{-9}}{10^6} \Rightarrow \lambda_{min} = 10^{-3}\,nm$$

107. [910] For photon,

$$\lambda_1 = \frac{h}{p} = \frac{6.6\times10^{-34}}{10^{-27}}$$

For a particle,

$$\lambda_2 = \frac{h}{mv} = \frac{6.6\times10^{-34}}{9.1\times10^{-31}\times10^6}$$

Therefore, $\frac{\lambda_1}{\lambda_2} = 910$

108. (a) For electron,

$$\lambda_1 = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$$ and For photon,

$$\lambda_2 = \frac{hc}{E}$$

$$\Rightarrow \frac{\lambda_1^2}{\lambda_2^2} = \frac{\frac{h^2}{2Em}}{\frac{h^2c^2}{E^2}} = \frac{E}{2mc^2} \Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{1}{c}\left(\frac{E}{2m}\right)^{\frac{1}{2}}$$

109. (b) According to Heisenberg uncertainty principle:

$$\Rightarrow \Delta x\Delta p \geq \frac{h}{4\pi}$$

$$\Rightarrow \Delta x(m\Delta v) \geq \frac{h}{4\pi}$$

$$\Rightarrow \Delta x\left(m\sqrt{\frac{3RT}{m}}\right) \geq \frac{h}{4\pi} \quad \left[v = \sqrt{\frac{3RT}{m}}\right]$$

$$\Rightarrow \Delta x \propto \frac{1}{\sqrt{m}}$$

$$\Rightarrow \frac{\Delta x_e}{\Delta x_p} = \sqrt{\frac{m_p}{m_e}}$$

110. (b) According to de-Broglie's hypothesis,

$$\lambda = \frac{h}{mv} \Rightarrow p = mv = \frac{h}{\lambda}$$

$$\Rightarrow K = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$$

Cut-off wavelength of emitted X-ray,

$$= \frac{hc}{K} = hc\times\frac{2m\lambda^2}{h^2} = \frac{2mc\lambda^2}{h}$$

111. (c) Let, $m_p = m, q_p = q$
$\therefore m_\alpha = 4\,m, q_\alpha = 2q$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}} \Rightarrow \lambda \propto \frac{1}{\sqrt{mq}}$$

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_p}\cdot\frac{q_\alpha}{q_p}} = \sqrt{\frac{4m}{m}\times\frac{2q}{q}} = \sqrt{4\times2}$$

$$= 2\times1.4 = 2.8$$

112. (d) de-Broglie wavelength,

$$\lambda \propto \frac{1}{\sqrt{m}}$$

$$\frac{\lambda_{electron}}{\lambda_{proton}} = \sqrt{\frac{m_{proton}}{m_{electron}}} = \sqrt{\frac{m_p}{m_e}}$$

113. (a) For electron,

$$(KE)_e = \frac{1}{2}mv^2 = \frac{pv}{2}$$

For photon,

$$(K.E)_p = \frac{hc}{\lambda} = pc \quad \left(p = \frac{h}{\lambda}\right)$$

$$\frac{KE_e}{KE_p} = \frac{pv/2}{pc} = \frac{v}{2c}$$

114. (d) According to the question,

$$\lambda' = \lambda\times\frac{75}{100} = \frac{3}{4}\lambda'$$

and $\lambda = \frac{h}{P} = \frac{h}{\sqrt{2mE}}$

$$\Rightarrow \frac{E'}{E} = \left(\frac{\lambda}{\lambda'}\right)^2 = \left(\frac{4}{3}\right)^2 \Rightarrow E' = \frac{16}{9}E$$

Therefore, extra energy required

$$= E' - E = \frac{16}{9}E - E = \frac{7}{9}E$$

115. (d) $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mK.E.}}$

For same K.E

$$\lambda \propto \frac{1}{\sqrt{m}}$$

$m_\alpha = 4m_p, m_p > m_e$

$$\therefore \lambda_e : \lambda_p : \lambda_\alpha = \frac{1}{\sqrt{m_e}} : \frac{1}{\sqrt{m_p}} : \frac{1}{\sqrt{4m_p}}$$

$\lambda_e, \lambda_p, \lambda_\alpha$

116. (b) We know that De Broglie wavelength

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}} \quad [E \rightarrow K.E.]$$

$$E = \frac{3}{2}KT \text{ for gas}$$

$$\Rightarrow \lambda = \frac{h}{\sqrt{3mKT}}$$

$$\Rightarrow \lambda = 6.26\times10^{-9}\,m$$

$$\therefore \lambda = 6.26\,nm$$

117. (c) We know that,

$$KE = \frac{P^2}{2m} \Rightarrow P = \sqrt{2mKE}$$

$$= \frac{6.6\times10^{-34}}{\sqrt{3\times9\times10^{-31}\times1.38\times10^{-23}\times300}}$$

Also, de-broglie wavelength, λ is given by $\lambda = \frac{h}{P}$

$$\lambda = \frac{h}{\sqrt{2mK}}$$

$\because \lambda \rightarrow$ same for both

$\therefore K_p < K_e$

Again $\lambda = \frac{h}{P}$

$\because P \rightarrow$ same for both

$\therefore P_p = P_e$

118. (d) Using de-Broglie equation for wave nature of particle:

$$\lambda = \frac{hc}{mv} \Rightarrow \lambda\alpha\frac{1}{m}$$

$$\Rightarrow \frac{\lambda_e}{\lambda_p} = \frac{m_p}{m_e} = 1836$$

119. (d) $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mqV}}$

$$\frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}} = \sqrt{1831.4} = 42.79$$

120. (c) $\frac{\lambda}{\lambda_e} = \frac{m_e v_e}{mv}$

$$m = \frac{1}{4}\cdot\frac{1}{2}m_e = \frac{1}{8}m_e$$

@FAKE_CBSE_X @RAJ_EDUNET

121. (c) We know that, $\lambda = \frac{h}{mv}$

Given, $\lambda_p = \lambda_\alpha$

$\Rightarrow \frac{h}{m_p v_p} = \frac{h}{m_\alpha v_\alpha}$

$\therefore \frac{v_p}{v_\alpha} = \frac{m_\alpha}{m_p} = \frac{4 \times m_p}{m_p} = 4$

122. (c) Fact based

123. (b) Momentum of mass M, $P_1 = MV_1$

Momentum of mass $3M$, $P_2 = 3MV_2$

Since, there is no external force

Therefore from conservation of momentum

$MV_1 = 3MV_2 = p$

$\lambda = \frac{h}{mv} = \frac{h}{p}$

$\frac{\lambda_1}{\lambda_2} = \frac{1}{1}$

124. (a) $p = \frac{h}{\lambda} = \frac{h}{\text{mV}}$

$\Rightarrow \frac{\lambda_{\text{particle}}}{\lambda_e} = \frac{m_e v_e}{m_p v_p} \Rightarrow 1.878 \times 10^{-4}$

$= \left(\frac{9.1 \times 10^{-31}}{m_p}\right)\left(\frac{1}{5}\right) \quad [\because V_P = 5V_e]$

$\Rightarrow m_p = \frac{9.1 \times 10^{-31}}{5 \times 1.878 \times 10^{-4}} = 9.7 \times 10^{-28}\text{kg}$

125. (d) λ for electron $= \frac{h}{\sqrt{2mE}}$

λ for photon $= \frac{hc}{E}$

Required ratio $= \frac{1}{c}\sqrt{\frac{E}{2m}}$

126. (c) $\lambda_D = \frac{h}{mv}$

$\therefore v = at$

$v = \frac{eE}{m}t$

$\lambda_D = \frac{h}{m\left(\frac{eE}{m}\right)t}, \lambda_D = \frac{h}{eEt}, \frac{d\lambda_d}{dt} = -\frac{h}{|e|Et^2}$

127. (b) $\lambda_0 = \frac{h}{\frac{m}{2}v_0} \quad \frac{m}{2}v_0 = \frac{m}{2}v_1 + \frac{m}{3}v_2$

$v_0 = v_2 - v_1$

$v_1 = \frac{v_0}{5}$

$\lambda_1 = \frac{h}{\frac{m}{2}\frac{v_0}{5}} = 5\lambda_0$

$\Delta\lambda = 4\lambda_0$

128. (b) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{E}}$

$\frac{\lambda}{\lambda/2} = \sqrt{\frac{E_f}{E_i}}$

$4E_i = E_f$

$\Rightarrow \Delta E = 4E_i - E_i = 3E$

129. (c) $\lambda = \frac{h}{p}$

$p = \sqrt{2mk} \quad \lambda \propto \frac{1}{\sqrt{m}}$

130. (a) Initially $m\left(\sqrt{2}v_0\right) = \frac{h}{\lambda_0}$

Velocity, $v = \sqrt{v_0^2 + v_0^2 + \left(\frac{eE_0}{m}t\right)^2}$

$= \sqrt{2v_0^2 + \frac{e^2E_0^2}{m^2}t^2}$

$= v_0\hat{i} + v_0\hat{j} + \frac{eE_0}{m}t\hat{k}$

So wavelength,

$\lambda = \frac{h}{mv} = \frac{h}{m\sqrt{2v_0^2 + \frac{e^2E_0^2}{m^2}t^2}}$

$\lambda = \frac{\lambda_0}{\sqrt{1 + \frac{e^2E_0^2}{2m^2v_0^2}t^2}}$

131. (a) $V_{rms} = \sqrt{\frac{3KT}{m}}$

$\lambda = \frac{h}{\sqrt{3KTm}}$

132. (b) de-Broglie wave length,

$\lambda = \frac{2\pi r}{n}$

$\lambda = \frac{2\pi \times 4.65 \times 10^{-10}}{3} = 9.7\text{Å}$

133. (d) $\Delta E = 5.6\text{ eV} - 0.7\text{ eV} = 4.9\text{ eV}$

Now $\lambda = \frac{hc}{\Delta E} = \frac{12410\text{ eV} - \text{A}^\circ}{4.9\text{ eV}} \approx 250\text{ nm}$

134. (d) $\bigcirc \longrightarrow \frac{h}{\lambda_1} = P_1 \quad \uparrow \bigcirc \; P_2 = \frac{h}{\lambda_2}$

$\vec{P}_1 = \frac{h}{\lambda_1}\hat{i} \;\&\; \vec{P}_2 = \frac{h}{\lambda_2}\hat{j}$

Using momentum conservation

$\vec{P} = \vec{P}_1 + \vec{P}_2 = \frac{h}{\lambda_1}\hat{i} + \frac{h}{\lambda_2}\hat{j}$

$|\vec{P}| = \sqrt{\left(\frac{h}{\lambda_1}\right)^2 + \left(\frac{h}{\lambda_2}\right)^2}$

$\frac{h}{\lambda} = \sqrt{\left(\frac{h}{\lambda_1}\right)^2 + \left(\frac{h}{\lambda_2}\right)^2}$

$\frac{1}{\lambda^2} = \frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2}$

135. (d) $\lambda_e = \lambda_{\text{photon}} \times 10^{-3}$

$\Rightarrow \frac{h}{mv} = \frac{c}{v} \times 10^{-3}\,s \Rightarrow v = \frac{hv}{mC \times 10^{-3}}$

$v_{m/s} = \frac{6.62 \times 10^{-34} \times 6 \times 10^{14}}{9.1 \times 10^{-31} \times 3 \times 10^8 \times 10^{-3}} = 1.45 \times 10^6$

136. (d)

let mass of B and C be m each. By conservation of momentum.

$2mv_0 = mv - \frac{mv}{2}$

$v = 4v_0$

$p_A = 2mv_0 \quad p_B = 4mv_0 \quad p_c = 2mv_0$

De-Broglie wavelength $\lambda = \frac{h}{p}$

$\lambda_A = \frac{h}{2mv_0}; \lambda_B = \frac{h}{4mv_0}; \lambda_C = \frac{h}{2mv_0}$

137. (c) $\lambda = \frac{h}{\sqrt{2mqV}} \quad \frac{\lambda_P}{\lambda_\alpha} = \sqrt{\frac{4 \times 1 \times 2500}{1 \times 1 \times 50}}$

$= 10\sqrt{2} = 14.14$

138. (d) $KE = \frac{P^2}{2m} = \frac{h^2}{2m\lambda^2}$

$= \frac{\left(6.62 \times 10^{-34}\right)^2}{2 \times 9.1 \times 10^{-31} \times \left(7.5 \times 10^{-12}\right)^2} \times$

$\frac{1}{1.6 \times 10^{-19}}\text{eV}$

$= 25\text{KeV}$

139. (c) $\vec{P}_x = \frac{h}{\lambda_x}\hat{i} \;\&\; \vec{P}_y = \frac{h}{\lambda_y}\hat{j}$

Using momentum conservation

$\vec{P} = \vec{P}_x + \vec{P}_y$

$\frac{h}{\lambda} = \frac{h}{\lambda_x} - \frac{h}{\lambda_y}, \quad \frac{1}{\lambda} = \frac{1}{\lambda_x} - \frac{1}{\lambda_y}$

@FAKE_CBSE_X_RAJ_EDUNET

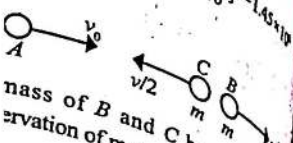
$$\frac{h}{\lambda}=\sqrt{\left(\frac{h}{\lambda_1}\right)^2+\left(\frac{h}{\lambda_2}\right)^2}$$

$$\frac{1}{\lambda^2}=\frac{1}{\lambda_1^2}+\frac{1}{\lambda_2^2}$$

d) $\lambda_e=\lambda_{photon}\times 10^{-3}$

$\Rightarrow \frac{h}{mv}=\frac{c}{v}\times 10^{-3}\ s \Rightarrow v=\frac{hv}{mc\times 10^{-3}}$

$=\frac{6.62\times10^{-34}\times6\times10^{14}}{9.1\times10^{-31}\times3\times10^{8}\times10^{-3}}=1.45\times10$



nass of B and C be m each. By

ervation of momentum

$=mv-\frac{mv}{2}$

$mv_0\ p_B=4mv_0\ p_c=2mv_0$

glie wavelength $\lambda=\frac{h}{p}$

$\frac{h}{mv_0};\lambda_B=\frac{h}{4mv_0};\lambda_C=\frac{h}{2mv_0}$

$\frac{h}{\sqrt{2mqV}}\ \frac{\lambda_p}{\lambda_\alpha}=\sqrt{\frac{4\times1\times2500}{1\times1\times50}}$

$=10\sqrt{2}=14.14$

$\frac{P^2}{2m}=\frac{h^2}{2m\lambda^2}$

$\frac{(6.62\times10^{-34})^2}{10^{-31}\times(7.5\times10^{-12})^2}\times$

$\frac{1}{1.6\times10^{-19}}eV$

& $\vec{P}_y=\frac{h}{\lambda_y}\hat{j}$

tum conservation

$\frac{1}{\lambda}=\frac{1}{\lambda_x}-\frac{1}{\lambda_y}$

$|\lambda|=\left|\frac{\lambda_x\lambda_y}{\lambda_x-\lambda_y}\right|$

140. [1] Let momentum of one photon is p and after reflection velocity of the mirror is v.

Conservation of linear momentum

$Np\hat{i}=-Np\hat{i}+mv\hat{i}$

$mv\hat{i}=2pN\hat{i}$

$mv=2Np$ ...(i)

since v is velocity of mirror (spring mass system) at mean position,

$v=A\omega$

Where A is maximum deflection of mirror from mean position. ($A=1\ \mu m$) and ω is angular frequency of mirror spring system,

momentum of 1 photon, $p=\frac{h}{\lambda}$

$mv=2Np$ ...(ii)

$mA\omega=2N\frac{h}{\lambda}$

$N=\frac{m\omega}{h}\times\frac{\lambda A}{2}$

given, $\frac{m\omega}{h}=\frac{10^{24}}{4\pi}m^{-2}, \lambda=8\pi\times10^{-6}$ m

$\therefore N=\frac{10^{24}}{4\pi}\times\frac{8\pi\times10^{-6}\times10^{-6}}{2}$

$N=10^{12}=x\times10^{12}$

JEE-Advanced

1. (d) The first photon will excite the hydrogen atom (in-ground state) to first excited state ($E_2-E_1=10.2\ eV$).

Hence, during de-excitation a photon of $10.2\ eV$ will be released.

The second photon of energy 15 eV can ionize the atom.

Hence, the balance energy i.e. (15 – 13.6) eV = 1.4 eV is retained by the electron.

Therefore, by the second photon an electron of energy, 1.4 eV will be released.

2.(a,d) $\frac{hc}{\lambda_a}=(E_4-E_1)$ and $\frac{hc}{\lambda_e}=(E_4-E_m)$

$\Delta p_a=\frac{(E_4-E_1)}{c}$ and $\Delta p_e=\frac{(E_4-E_m)}{c}$

$\Rightarrow \frac{\lambda_a}{\lambda_e}=\frac{(E_4-E_m)}{E_4-E_1}=\frac{1}{5}=\frac{\frac{1}{m^2}-\frac{1}{16}}{\frac{15}{16}}$

$\Rightarrow \frac{15}{16\times5}=\frac{1}{m^2}-\frac{1}{16}\Rightarrow\frac{1}{m^2}=\frac{1}{4}$

$\Rightarrow m=2$

$\frac{\Delta p_a}{\Delta p_e}=\frac{(E_4-E_1)}{(E_4-E_m)}=\frac{15\times16}{16\times3}=5$

$\frac{hc}{\lambda_e}=(13.6eV)\times\frac{3}{16}$

$\Rightarrow \lambda_e\cong487$ nm

$\because KE_n\propto\frac{Z^2}{n^2}\Rightarrow\frac{K_2}{K_1}=\frac{1}{2^2}=\frac{1}{4}$

3. (i)-A; (ii)-F; (iii)-E; (iv)-C

4. Area of plates $A=5\times10^{-4}\ m^2$

Distance between the plates $d=1$ cm $=10^{-2}$ m

(a) Number of photoelectrons emitted upto $t=10s$ are

(number of photons falling in unit

$n=\frac{(\text{area in unit time})\times(\text{area}\times\text{time})}{10^6}$

$=\frac{1}{10^6}[(10)^{16}\times(5\times10^{-4})\times(10)]$

$=5.0\times10^7$

(b) At time, $t=10s$

Charge on plate A, $q_A=+ne=(5.0\times10^7)(16\times10^{-19})=8.0\times10^{-12}\ C$

and charge on plate B,

$q_B=(33.7\times10^{-12}-8.0\times10^{-12})$

$=25.7\times10^{-12}\ C$

$\therefore$ Electric field between the plates,

$E=\frac{(q_B-q_A)}{2A\varepsilon_0}$

or $E=\frac{(25.7-8.0)\times10^{-12}}{2\times(5\times10^{-4})(8.85\times10^{-12})}$

$=2\times10^3$ N/C

(c) Energy of photoelectrons at plate A

$=E-W=(5-2)$eV $=3$ eV

Increase in energy of photoelectrons

$=(eEd)$ joule $=(Ed)$ eV

$=(2\times10^3)(10^{-2})$ eV $=20$ eV

Energy of photoelectrons at plate B

$=(20+3)$ eV $=23$ eV

5. (a) $h\nu-\phi=6$eV

$\frac{hc}{\lambda}-\phi=6$eV ...(i)

and $\frac{hc}{4\lambda}-\phi=0.6$eV ...(ii)

(i) – (ii)

$\frac{3hc}{4\lambda}=5.4$eV

$\therefore \lambda=\frac{3hc}{4\times5.4\text{eV}}=\frac{3\times1.24\times10^{-6}}{4\times5.4}$

$=1.72\times10^{-7}$ m

from equation (i)

$\frac{hc}{1.72\times10^{-7}}\times\frac{1}{1.6\times10^{-19}}-\phi=6$eV

$\frac{2\times10^{-25}}{2.75\times10^{-26}}-\phi=6$

$\Rightarrow \phi=(7.27-6)\cong1.2$ eV

6. (d) According to photoelectric effect equation

$KE_{max}=\frac{hc}{\lambda}-\phi_0$

$\frac{p^2}{2m}=\frac{hc}{\lambda}-\phi_0\ [KE=p^2/2m]$

$\frac{(h/\lambda_d)^2}{2m}=\frac{hc}{\lambda}-\phi_0\ [p=h/\lambda]$

Assuming small changes, differentiating both sides,

$\frac{h^2}{2m}\left(-\frac{2d\lambda_d}{\lambda_d^3}\right)=-\frac{hc}{\lambda^2}d\lambda, \frac{d\lambda_d}{d\lambda}\propto\frac{\lambda_d^3}{\lambda^2}$

7. (b) $\frac{hc}{\lambda}-\phi=eV_0\ \frac{hc}{0.3\times10^{-6}}-\phi$

$=2e\ \frac{hc}{0.4\times10^{-6}}-\phi=1e$

Subtracting Eq. (ii) from Eq. (i)

$hc\left(\frac{1}{0.3}-\frac{1}{0.4}\right)10^6=e$

$hc\left(\frac{0.1}{0.12}\times10^6\right)=e$

$h=0.64\times10^{-33}=6.4\times10^{-34}\ J-s$

8. (a) Energy corresponding to 248 nm wavelength $=\frac{1240}{248}eV=5eV$

Energy corresponding to 310 nm wavelength

$=\frac{1240}{310}eV=4eV$

$\frac{KE_1}{KE_2}=\frac{u_1^2}{u_2^2}=\frac{4}{1}=\frac{5eV-W}{4eV-W}$

$\Rightarrow 16-4W=5-W\Rightarrow11=3W$

$\Rightarrow W=11/3=3.67eV\cong3.7eV$

@FAKE_CBSE_X @RAJ_EDUNET

9. (*a*) $E_1 = \frac{1240}{550} = 2.25$ eV,

$E_2 = \frac{1240}{450} = 2.75$ eV

$E_3 = \frac{1240}{350} = 3.54eV$

E_1 cannot emit photoelectrons from q and r plates. E_2 can not emit photoelectrons from r.

Further, work function of p is least and it can emit photoelectrons from all three wavelengths. Hence magnitude of its stopping potential and saturation current both will be maximum.

10. (*a*) $i = \frac{q}{t} = \frac{ne}{t}$

$\therefore\ n = \frac{it}{e}$

Substituting, $i = 3.2 \times 10^{-3}A$, $e = 1.6 \times 10^{-19}C$ and $t = 1s$

We get, $n = 2 \times 10^{16}$

11. (*a*) Wavelength λ_k is independent of the accelerating voltage (V), while the minimum wavelength λ_c is inversely proportional to V. Therefore, as V is increased, λ_k remains unchanged whereas λ_c decreases or $\lambda_k - \lambda_c$ will increase.

12. (*c*) $\lambda(\text{in Å}) = \frac{12375}{W(\text{eV})} = \frac{12375}{4.0}$ Å $\approx$ Å

or $\lambda \approx 309.3$ nm ≈ 310 nm

13. (*b*) Stopping potential is the negative potential applied to stop the electrons having maximum kinetic energy. Therefore, stopping potential will be 4 V.

14. (*d*) $K_{max} = \frac{hc}{\lambda_{ph}} - \phi$

Kinetic energy of electron reaching the anode will be $K = \frac{hc}{\lambda_{ph}} - \phi + eV$

Now, $\lambda_e = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2m\left(\frac{hc}{\lambda_{ph}} - \phi + eV\right)}}$

If eV >> ϕ then, $\lambda_e = \frac{h}{\sqrt{2m\left(\frac{hc}{\lambda_{ph}} + eV\right)}}$

If $V_f = 4V_i$ then, $(\lambda_e)_f = \frac{(\lambda_e)_i}{2}$

15. (*a,c*) $eV_0 = \frac{hc}{\lambda} - W$ $V_0 = \left(\frac{hc}{e}\right)\left(\frac{1}{\lambda}\right) - \frac{W}{e}$

V_0 versus $\frac{1}{\lambda}$ graph is in the form $y = mx - c$

Therefore option (*c*) is correct.

Clearly, V_0 versus λ graph is not a straight line but V_0 decreases with increase in λ and V_0 becomes zero when $\frac{hc}{\lambda} = W$.

i.e. $\lambda = \lambda_0$ (Threshold wavelength)

$\therefore$ Option (*a*) is also correct.

16. (*a, c*) From the relation,

$eV = \frac{hc}{\lambda} - \phi$ or $V = \left(\frac{hc}{e}\right)\left(\frac{1}{\lambda}\right) - \frac{\phi}{e}$

This is equation of straight line.

Slope is $\tan\theta = \frac{hc}{e}$

$\phi_1 : \phi_2 : \phi_3 = \frac{hc}{\lambda_{01}} : \frac{hc}{\lambda_{02}} : \frac{hc}{\lambda_{03}}$

$= \frac{1}{\lambda_{01}} : \frac{1}{\lambda_{02}} : \frac{1}{\lambda_{03}} = 1 : 2 : 4$

$\frac{1}{\lambda_{01}} = 0.001$ nm^{-1} or $\lambda_{01} = 10000$ Å

$\frac{1}{\lambda_{02}} = 0.002$ nm^{-1} or $\lambda_{02} = 5000$ Å

$\frac{1}{\lambda_{03}} = 0.004$ nm^{-1} or $\lambda_{03} = 2500$ Å

Violet colour has wavelength 4000 Å.

So, violet colour can eject photoelectrons from metal-1 and metal-2.

17. (*a, b, c*) $K_{max} = E - W$

Therefore,

$T_A = 4.25 - W_A$ ...(*i*)

$T_B = (T_A - 1.50) = 4.70 - W_B$ ...(*ii*)

From Eqs. (*i*) and (*ii*),

$W_B - W_A = 1.95$ eV ...(*iii*)

de-Broglie wavelength is given by

$\lambda = \frac{h}{\sqrt{2\,\text{Km}}}$ or $\lambda \propto \frac{1}{\sqrt{K}}$

$K = KE$ of electron

$\therefore\ \frac{\lambda_B}{\lambda_A} = \sqrt{\frac{K_A}{K_B}}$ or $2 = \sqrt{\frac{T_A}{T_A - 1.5}}$

This gives, $T_A = 2$ eV

From Eq. (*i*) $W_A = 4.25 - T_A = 2.25$ eV

From Eq. (*iii*) $W_B = W_A + 1.95$eV

$= (2.25 + 1.95)$ eV or $W_B = 4.20$ eV

$T_B = 4.70 - W_B = 4.70 - 4.20 = 0.50$ eV

18. (*b,d*) Stopping potential depends on two factors – one the energy of incident light and the other the work function of the metal. By increasing the distance of source from the cell, neither of the two change. Therefore, stopping potential remains the same.

Saturation current is directly proportional to the intensity of light incident on cell and for a point source, intensity $I \propto 1/r^2$

19. (*c,d*) For photoemission to take place, wavelength of incident light should be less than the threshold wavelength. Wavelength of ultraviolet light < 5200 Å while that of infrared radiation > 5200 Å.

20. [3] $Rz^2\left(\frac{16-9}{9\times16}\right) = \frac{7}{9\times16}Rz^2$

$E = K_{max} + \phi = K_{max} + \frac{hc}{\lambda_0}$

$= 1.95 + \frac{1240}{310} = 1.95 + 4 = 5.95$ eV

$\frac{hc}{\lambda} = 5.95$ eV, $\frac{hc \times 7Rz^2}{9\times16} = 5.95$

$\therefore\ Z = 3$

21. [6] $E_P = 2E_Q = 2E_R = E$(assume)

For metal P and Q,

$E_1 - 4 = E_P = E$

$E_1 - 4.5 = E_A = E/2$ ...(1)

Subtracting equation (2) from (1), we get ...(2)

$E/2 = 0.5$

For metal R

$E_2 - 5.5 = E_R = E/2 = 0.5 \Rightarrow E_2 = 6$

22. [1] $eV_0 = hf - W$ $\therefore\ V_0 = \left(\frac{h}{e}\right)f - \frac{W}{e}$

V_0 versus f graph is a straight line with slope $= \frac{h}{e} = a$ universal constant.

Therefore, the ratio of two slopes should be 1.

23. [7] Photo emission will stop when potential on silver sphere becomes equal to the stopping potential.

$\therefore\ \frac{hc}{\lambda} - W = eV_0$

Here, $V_0 = \frac{1}{4\pi\varepsilon_0}\frac{ze}{r}$

$\therefore\ \frac{hc}{\lambda} - W = \frac{1}{4\pi\varepsilon_0}\frac{ne^2}{e}$

$\therefore\ \left(\frac{1240}{200}\text{eV}\right) - (4.7\text{ eV})$

$= \frac{9\times10^9 \times n \times 1.6\times10^{-19}}{10^{-2}}$

$(6.2 - 4.7) \times 1.6 \times 10^{-19}$

$= \frac{9\times10^9 \times n \times (1.6\times10^{-19})^2}{10^{-2}}$

or $n = \frac{1.5\times10^{-2}}{9\times1.6\times10^{-10}} = 1.04 \times 10^7$

$\therefore$ Answer is 7.

24. $K_{max} = h\nu - W$

Therefore, K_{max} is linearly dependent on frequency of incident radiation.

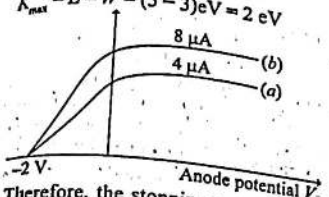
@FAKE_CBSE_Y@RAJ_EDUNET

26. [False] Maximum energy of photoelectrons increases with increase in frequency of incident light. So, if intensity is increased by increasing frequency of incident light, maximum energy will increase. If intensity is increased merely by increasing number of photons incident per second, maximum energy of photoelectrons will not change. So, question is incomplete because it is not told how the intensity is increased.

27. [False] Kinetic energy of photoelectrons depends upon the frequency of incident radiation.

27. Maximum kinetic energy of the photoelectrons would be

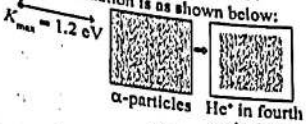
$K_{max} = E - W = (5-3)\text{eV} = 2\text{ eV}$



Therefore, the stopping potential is 2 V. Saturation current depends on the intensity of light incident. When the intensity is doubled the saturation current will also become two fold. The corresponding graphs are shown in above figure.

28. Energy of incident photons,
$E_1 = 10.6\text{ eV} = 10.6 \times 1.6 \times 10^{-19}\text{ J}$
$= 16.96 \times 10^{-19}\text{ J}$
Energy incident per unit area per unit time (intensity) = 2 J
$\therefore$ Number of photons incident on unit area in unit time
$= \dfrac{2}{16.96\times10^{-19}} = 1.18 \times 10^{18}$
Therefore, number of photons incident per unit time on given area $(1.0 \times 10^{-4}\text{ m}^2)$
$(1.18 \times 10^{18})(1.0 \times 10^{-4}) = 1.18 \times 10^{14}$
But only 0.53% of incident photons emit photoelectrons
$\therefore$ Number of photoelectrons emitted per second (n)
$n = \left(\dfrac{0.53}{100}\right)(1.18 \times 10^{14})$
$n = 6.25 \times 10^{11}$
$K_{min} = 0$
and K_{max} = E_1 – work function
$= (10.6 - 5.6)\text{eV} = 5.0\text{ eV}$
$\therefore$ $K_{max} = 5.0$ eV and $K_{min} = 0$

29. Given work function, $W = 1.9$ eV
Wavelength of incident light, $\lambda = 400$ nm
$\therefore$ Energy of incident light, $E = \dfrac{hc}{\lambda}$
$= 3.1\text{eV}$
(Substituting the values of h, c and λ)
Therefore, maximum kinetic energy of photoelectrons
$K_{max} = E - W = (3.1 - 1.9) = 1.2\text{ eV}$
Now the situation is as shown below:



Energy of electron in 4th excited state of He^+ $(n = 5)$ will be
$E_5 = -13.6\dfrac{Z^2}{n^2}\text{ eV} \Rightarrow E_5 = -(13.6)\dfrac{(2)^2}{(5)^2}$
$= -2.2\text{ eV}$
Therefore, energy released during the combination
$= 1.2 - (-2.2) = 3.4\text{ eV}$
Similarly, energies in other energy states of He^+ will be
$E_4 = -13.6\dfrac{(2)^2}{(4)^2} = -3.4\text{ eV}$
$E_3 = -13.6\dfrac{(2)^2}{(3)^2} = -6.04\text{ eV}$
$E_2 = -13.6\dfrac{(2)^2}{(2)^2} = -13.6\text{ eV}$
The possible transitions are
$\Delta E_{5\to4} = E_5 - E_4 = 1.2\text{ eV} < 2\text{ eV}$.
$\Delta E_{5\to3} = E_5 - E_3 = 3.84\text{ eV}$
$\Delta E_{5\to2} = E_5 - E_2 = 11.4\text{ eV} > 4\text{ eV}$
$\Delta E_{4\to3} = E_4 - E_3 = 2.64\text{ eV}$
$\Delta E_{4\to2} = E_4 - E_2 = 10.2\text{ eV} > 4\text{ eV}$
Hence, the energy of emitted photons in the range of 2 eV and 4 eV are
3.4 eV during combination and
3.84 eV and 2.64 eV after combination.

30. (a) Energy of emitted photons
$E_1 = 5.0\text{ eV} = 5.0 \times 1.6 \times 10^{-19}\text{J} = 8.0 \times 10^{-19}\text{ J}$
Power of the point source is 3.2×10^{-3} W or 3.2×10^{-3} J/s.
Therefore, energy emitted per second,
$E_2 = 3.2 \times 10^{-3}$ J
Hence, number of photons emitted per second $n_1 = \dfrac{E_2}{E_1}$ or $n_1 = \dfrac{3.2\times10^{-3}}{8.0\times10^{-19}}$
$n_1 = 4.0 \times 10^{15}$ photon/s
Number of photons incident on unit area at a distance of 0.8 m from the source S will be
$n_2 = \dfrac{n_1}{4\pi(0.8)^2} = \dfrac{4.0\times10^{15}}{4\pi(0.64)}$
$= 5 \times 10^{14}$ photon/s-m²
The area of metallic sphere over which photons will fall is
$A = \pi r^2 = \pi(8 \times 10^{-1})^2\text{ m}^2 = 2.01 \times 10^{-4}\text{ m}^2$
Therefore, number of photons incident on the sphere per second are
$n_3 = n_2 A = (5.0 \times 10^{14} \times 2.01 \times 10^{-4}) \approx 10^{11}$/s
One photoelectron is emitted for every 106 photons, hence number of photoelectrons emitted per second.
$n = \dfrac{n_3}{10^6} = \dfrac{10^{11}}{10^6} = 10^5$/s or $n = 10^5$/s

(b) Maximum kinetic energy of photoelectrons
K_{max} = Energy of incident photons – work function
$= (5.0 - 3.0)\text{eV} = 2.0\text{eV}$
$= 2.0 \times 1.6 \times 10^{-19}\text{ J}$
$K_{max} = 3.2 \times 10^{-19}$ J
The de-Broglie wavelength of these photoelectrons will be
$\lambda_1 = \dfrac{h}{p} = \dfrac{h}{\sqrt{2K_{max}m}}$
Here, h = Planck's constant and m = mass of electron
$\lambda_1 = \dfrac{6.63\times10^{-34}}{\sqrt{2\times3.2\times10^{-19}\times9.1\times10^{-31}}}$
$= 8.68 \times 10^{-10} = 8.68$ Å
Wavelength of incident light λ_2 (in Å)
$= \dfrac{12375}{E_1(in\,eV)}$
or $\lambda_2 = \dfrac{12375}{5} = 2475$ Å
$\dfrac{\lambda_2}{\lambda_1} = \dfrac{2475}{8.68} = 285.1$

(c) As soon as electrons are emitted from the metal sphere, it gets positively charged and acquires positive potential. The positive potential gradually increases as more and more photoelectrons are emitted from its surface. Emission of photoelectrons is stopped when its potential is equal to the stopping potential required for fastest moving electrons. Because this positive potential/charge will attract the electrons.

(d) As discussed in part (c), emission of photoelectrons is stopped when potential on the metal sphere is equal to the stopping potential of fastest moving electrons.
Since, $K_{max} = 2.0$ eV
Therefore, stopping potential $V_0 = 2$ V.
Let q be the charge required for the potential on the sphere to be equal to stopping potential or 2 V. Then
$2 = \dfrac{1}{4\pi\varepsilon_0}\cdot\dfrac{q}{r} = (9.0\times10^9)\dfrac{q}{80\times10^{-3}}$

@FAKE_RSE_RAJ_EDUNET

$\therefore\ q = 1.78 \times 10^{-12}$ C

Photoelectrons emitted per second $= 10^5$ [Part (*a*)]

or charge emitted per second $= (1.6 \times 10^{-19}) \times 10^5$ C $= 1.6 \times 10^{-14}$ C

Therefore, time required to acquire the charge q will be

$$t = \frac{q}{1.6\times10^{-14}}s = \frac{1.78\times10^{-12}}{1.6\times10^{-14}}s$$

or $t = 111$s

31. (*a*) From Einstein's equation of photoelectric effect,

Energy of photons causing the photoelectric emission = Maximum kinetic energy of emitted photons + work function

or $E = K_{max} + W = (0.73 + 1.82)$ eV

or $E = 2.55$ eV

(*b*) In case of a hydrogen atom,

$E_1 = -13.6$ eV, $E_2 = -3.4$ eV,

$E_3 = -1.5$ eV,

$E_4 = -0.85$ eV

Since, $E_4 - E_2 = 2.55$ eV

Therefore, quantum numbers of the two levels involved in the emission of these photons are 4 and $2(4 \to 2)$.

(*c*) Change in angular momentum in transition from 4 to 2 will be

$$\Delta L = L_2 - L_4$$

$$= 2\left(\frac{h}{2\pi}\right) - 4\left(\frac{h}{2\pi}\right) \text{ or } \Delta L = -\frac{h}{\pi}$$

(*d*) From conservation of linear momentum

|Momentum of hydrogen atom| = |Momentum of emitted photon|

or $mv = \dfrac{E}{c}$

(m = mass of hydrogen atom)

or $v = \dfrac{E}{mc}$

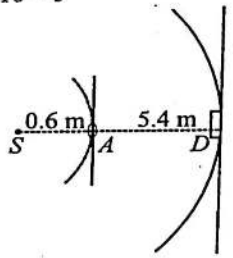
$$= \frac{(2.55\times1.6\times10^{-19}\text{ J})}{(1.67\times10^{-27}\text{ kg})(3.0\times10^{8}\text{ m/s})}$$

$v = 0.814$ m/s

32. (*a*) Energy of one photon,

$$E = \frac{hc}{\lambda} = \frac{(6.6\times10^{-34})(3.0\times10^{8})}{6000\times10^{-10}}$$

$= 3.3 \times 10^{-19}$ J



Power of the source is 2W or 2 J/s. Therefore, number of photons emitting per second,

$$n_1 = \frac{2}{3.3\times10^{-19}} = 6.06 \times 10^{18}\text{/s}$$

At distance 0.6 m, number of photons incident per unit area per unit time:

$$n_2 = \frac{n_1}{4\pi(0.6)^2} = 1.34 \times 10^{18}\text{/m}^2\text{/s}$$

Area of aperture is

$$S_1 = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.1)^2 = 7.85 \times 10^{-3}\text{ m}^2$$

$\therefore$ Total number of photons incident per unit time on the aperture,

$n_3 = n_2 S_1 = (1.34 \times 10^{18})$ (7.85×10^{-3})/s $= 1.052 \times 10^{16}$/s

The aperture will become new source of light.

Now, these photons are further distributed in all directions. Hence, at the location of detector, photons incident per unit area per unit time

$$n_4 = \frac{n_3}{4\pi(6-0.6)^2} = \frac{1.052\times10^{16}}{4\pi(5.4)^2}$$

$= 2.87 \times 10^{13}$ s^{-1}m^{-2}

This is the photon flux at the centre of the screen. Area of detector is 0.5 cm^2 or 0.5×10^{-4} m^2. Therefore, total number of photons incident on the detector per unit time

$n_5 = (0.5 \times 10^{-4})$ (2.87×10^{13})

$= 1.435 \times 10^9$ s^{-1}

The efficiency of photoelectron generation is 0.9. Hence, total photoelectrons generated per unit time

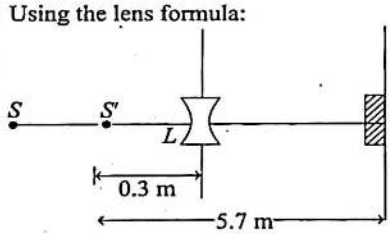
$n_6 = 0.9\ n_5 = 1.2915 \times 10^9$s^{-1}

or, photocurrent in the detector

$i = (e)n_6 = (1.6 \times 10^{-19})$ (1.2915×10^9)

$= 2.07 \times 10^{-10}$ A

(*b*) Using the lens formula:



$$\frac{1}{v} - \frac{1}{-0.6} = \frac{1}{-0.6} \text{ or } v = -0.3\text{ m}$$

i.e. image of source (say S', is formed at 0.3 m) from the lens.

Total number of photons incident per unit time on the lens are still n_3 or 1.052×10^{16}/s. 80% of it transmits to second medium. Therefore, at a distance of 5.7 m from S' number of photons incident per unit area per unit time will be

$$n_7 = \frac{(80/100)(1.052\times10^{16})}{(4\pi)(5.7)^2}$$

$= 2.06 \times 10^{13}$ s^{-1}m^{-2}

This is the photon flux at the detector

New, value of photocurrent is

$i' = (2.06 \times 10^{13})$ (0.5×10^{-4}) (0.9) $(1.6 \times 10^{-19}) = 1.483 \times 10^{-10}$ A

(*c*) Energy of incident photons (in both the cases):

$$E = \frac{12375\text{ eV-Å}}{6000\text{ Å}} = 2.06\text{ eV}$$

Work function $W = 1.0$ eV

$\therefore$ Maximum kinetic energy of photoelectrons in both cases,

$K_{max} = E - W = 1.06$ eV

or the stopping potential will be 1.06 V.

33. The stopping potential for shorter wavelength is 3.95 V i.e. maximum kinetic energy of photoelectrons corresponding to shorter wavelength will be 3.95 eV. Further energy of incident photons corresponding to shorter wavelength will be in transition from $n = 4$ to $n = 3$.

$$E_{4-3} = E_4 - E_3 = \frac{-(13.6)(3)^2}{(4)^2} - \left[\frac{-(13.6)(3)^2}{(3)^2}\right]$$

$= 5.95$ eV

Now, from the equation, $K_{max} = E - W$

we have $W = E - K_{max} = E_{4-3} - K_{max}$

$= (5.95 - 3.95)$ eV $= 2$ eV

Longer wavelength will correspond to transition from $n = 5$ to $n = 4$. From the relation,

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

The longer wavelength,

$$\frac{1}{\lambda} = (1.094\times10^7)(3)^3\left(\frac{1}{16} - \frac{1}{25}\right)$$

or $\lambda = 4.514 \times 10^{-7}$ m $= 4514$ Å

Energy corresponding to this wavelength,

$$E = \frac{12375\text{eV-Å}}{4514\text{Å}} = 2.74\text{eV}$$

$\therefore$ Maximum kinetic energy of photoelectrons

$K_{max} = E - W = - = (2.74 - 2)$ eV $= 0.74$ eV

or the stopping potential is 0.74 V.

34. Energy of photon having wavelength 4144Å

$$E_1 = \frac{12375}{4144}\text{ eV} = 2.99\text{ eV}$$

Similarly, $E_2 = \dfrac{12375}{4972}$ eV $= 2.49$ eV

$$E_3 = \frac{12375}{6216}\text{ eV} = 1.99\text{ eV}$$

@FAKE_CBSE_@RAJ_PHYSICS

Only E_1 and E_2 are greater than the work function $W = 2.3$ eV, hence only first two wavelengths are capable for ejecting photoelectrons. Given intensity is equally distributed in all wavelengths. Therefore, intensity corresponding to each wavelength is

$\frac{3.6\times10^{-3}}{3} = 1.2 \times 10^{-3}$ W/m²

Or energy incident per second in the given area ($A = 1.0$ cm² $= 10^{-4}$ m²) is

$P = 1.2 \times 10^{-3} \times 10^{-4}$

$= 1.2 \times 10^{-7}$ J/s

Let n_1 be the number of photons incident per unit time in the given area corresponding to first wavelength. Then

$n_1 = \frac{P}{E_1} = \frac{1.2\times10^{-7}}{2.99\times1.6\times10^{-19}} = 2.5 \times 10^{11}$

Similarly, $n_2 = \frac{P}{E_2} = \frac{1.2\times10^{-7}}{2.49\times1.6\times10^{-19}}$

$= 3.0 \times 10^{11}$

Since, each energetically capable photon ejects electron, total number of photoelectrons liberated in 2 s.

$= 2(n_1 + n_2) = 2(2.5 + 3.0) \times 10^{11}$

$= 1.1 \times 10^{12}$

35. (*a*) De-Broglie wavelength is $\lambda = \frac{h}{\sqrt{2mE}}$ ...(1)

Where E is the kinetic energy of the electrons. The cut-off wavelength is

$\lambda_0 = \frac{hc}{E}$

From equation (1):

$E = \frac{h^2}{2m\lambda^2}$, Hence, $\lambda_0 = \frac{2mc\lambda^2}{h}$

36. (*b*) $\lambda = \frac{h}{p}$ photon energy $E = hh$

So, $\lambda_1 = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$ ...(*i*)

$\Rightarrow E = h\nu_2 = \frac{h_c}{\lambda_2}$

$\lambda_2 = \frac{h_c}{E}$ ...(*ii*)

from eq (*i*) & (*ii*)

$\frac{\lambda_1}{\lambda_2} = \frac{h\sqrt{2mE}}{\left(\frac{h_c}{E}\right)} \sim \frac{E}{\sqrt{E}} = E^{1/2}$

So, $\lambda_1 = \frac{h}{p} = \frac{h}{\sqrt{2mE}} \rightarrow$

$\Rightarrow E = h\nu_2 = \frac{h_c}{\lambda_2}$

$\lambda_2 = \frac{h_c}{E}$

From eq (*i*) & (*ii*),

$\frac{\lambda_1}{\lambda_2} = \frac{h\sqrt{2mE}}{\left(\frac{h_c}{E}\right)} \sim \frac{E}{\sqrt{E}} = E^{1/2}$

37. (*c*) From law of conservation of momentum, $p_1 = p_2$ (in opposite directions)

Now de-Broglie wavelength is given by

$\lambda = \frac{h}{p}$, where h = Planck's constant

Since magnitude of linear momentum (p) of both the particles is equal, therefore $\lambda_1 = \lambda_2$ or $\lambda_1/\lambda_2 = 1$

38. [1] Let momentum of one photon is p and after reflection velocity of the mirror is v.

Conservation of linear momentum

$Np\hat{i} = -Np\hat{i} + mv\hat{i}$, $mv\hat{i} = 2pN\hat{i}$

$mv = 2Np$ ...(*i*)

since v is velocity of mirror (spring mass system) at mean position,

$v = A\Omega$

Where A is maximum deflection of mirror from mean position. ($A = 1$ μm) and Ω is angular frequency of mirror spring system,

momentum of 1 photon, $p = \frac{h}{\lambda}$

$mv = 2Np$ ...(*ii*)

$mA\Omega = 2N\frac{h}{\lambda}$, $N = \frac{m\Omega}{h} \times \frac{\lambda A}{2}$

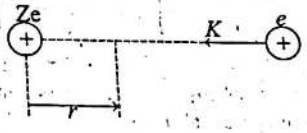
given, $\frac{m\Omega}{h} = \frac{10^{24}}{4\pi} m^{-2}$,

$\lambda = 8\pi \times 10^{-6}$ m

$\therefore N = \frac{10^{24}}{4\pi} \times \frac{8\pi\times10^{-6}\times10^{-6}}{2}$

$N = 10^{12} = x \times 10^{12}$

39. [7]



r = closest distance = 10 fm.

From energy conservation, we have

$K_i + U_i = K_f + U_f$

or $K + 0 = 0 + \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r}$

or $K = \frac{1}{4\pi\varepsilon_0} \cdot \frac{(120e)(e)}{r}$ ...(*i*)

de-Broglie wavelength

$\lambda = \frac{h}{\sqrt{2Km}}$ ...(*ii*)

Substituting the given values in above two equations, we get

$\lambda = 7 \times 10^{-15}$ m = 7 fm

40. [3] $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2Km}} = \frac{h}{\sqrt{2qVm}}$ or $\lambda \propto \frac{1}{\sqrt{qm}}$

$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{q_\alpha}{q_p} \cdot \frac{m_\alpha}{m_p}} = \sqrt{\frac{(2)(4)}{(1)(1)}} = 2.828$

The nearest integer is 3.

∴ Answer is 3.

41. For $0 \le x \le 1$, $PE = E_0$

∴ Kinetic energy K_1 = Total energy − PE

$= 2E_0 - E_0 = E_0$

$\therefore \lambda_1 = \frac{h}{\sqrt{2mE_0}}$ ...(*i*)

For $x > 1$, $PE = 0$

∴ Kinetic energy K_2 = Total energy $= 2E_0$

$\therefore \lambda_2 = \frac{h}{\sqrt{2m(2E_0)}}$ ...(*ii*)

From Eqs. (*i*) and (*ii*), we have

$\frac{\lambda_1}{\lambda_2} = \sqrt{2}$

42. (*a*) Kinetic energy of electron in the orbits of hydrogen and hydrogen like atoms = | Total energy |

∴ Kinetic energy = 3 4 . eV

(*b*) The de-Broglie wavelength is given by

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2Km}}$

Here, K = kinetic energy of electron

Substituting the values, we have

$\lambda = \frac{(6.6\times10^{-34}\text{ J-s})}{\sqrt{2(3.4\times1.6\times10^{-19}\text{ J})(9.1\times10^{-31}\text{ kg})}}$

$\lambda = 6.63 \times 10^{-10}$ m or $\lambda = 6.63$Å

@FAKE_CBSE_X @RAJEDUNET

Atoms

Scan for Sol.

JEE-Main

Bhor's Atomic Model and Hydrogen Spectrum

1. The radius of third stationary orbit of electron for Bohr's atom is R. The radius of fourth stationary orbit will be:

[27 Jan, 2024 (Shift-I)]

(a) $\frac{4}{3}R$ (b) $\frac{16}{9}R$ (c) $\frac{3}{4}R$ (d) $\frac{9}{16}R$

2. If Rydberg's constant is R, the longest wavelength of radiation in Paschen series will be $\frac{\alpha}{7R}$, where $\alpha =$ _____.

[27 JAN, 2024 (Shift-II)]

3. Given below are two statements: **[29 Jan, 2024 (Shift-II)]**

Statement-I: Most of the mass of the atom and all its positive charge are concentrated in a tiny nucleus and the electrons revolve around it, is Rutherford's model.

Statement-II: An atom is a spherical cloud of positive charges with electrons embedded in it, is a special case of Rutherford's model. In the light of the above statements, choose the most appropriate from the options given below.

(a) Both Statement-I and Statement-II are false

(b) Statement-I is false but Statement-II is true

(c) Statement-I is true but Statement-II is false

(d) Both Statement-I and Statement-II are true

4. Hydrogen atom is bombarded with electrons accelerated through a potential different of V, which causes excitation of hydrogen atoms. If the experiment is being formed at T = 0 K. The minimum potential difference needed to observe any Balmer series lines in the emission spectra will be $\frac{\alpha}{10}$ V, where $\alpha =$ _____.

[29 Jan, 2024 (Shift-II)]

5. The ratio of the magnitude of the kinetic energy to the potential energy of an electron in the 5th excited state of a hydrogen atom is: **[30 Jan, 2024 (Shift-I)]**

(a) 4 (b) $\frac{1}{4}$ (c) $\frac{1}{2}$ (d) 1

6. A electron of hydrogen atom on an excited state is having energy $En = -0.85$ eV. The maximum number of allowed transitions to lower energy level is _____. **[30 Jan, 2024 (Shift-I)]**

7. An electron revolving in n^{th} Bohr orbit has magnetic moment μ_n. If $\mu_n \alpha n^x$, the value of x is: **[30 Jan, 2024 (Shift-II)]**

(a) 2 (b) 1 (c) 3 (d) 0

8. If the wavelength of the first member of Lyman series of hydrogen is λ. The wavelength of the second member will be **[31 Jan, 2024 (Shift-I)]**

(a) $\frac{27}{32}\lambda$ (b) $\frac{32}{27}\lambda$ (c) $\frac{27}{5}\lambda$ (d) $\frac{5}{27}\lambda$

9. The minimum energy required by a hydrogen atom in ground state to emit radiation in Balmer series is nearly: **[1 Feb, 2024 (Shift-I)]**

(a) 1.5 eV (b) 13.6 eV (c) 1.9 eV (d) 12.1 eV

10. A particular hydrogen-like ion emits the radiation of frequency 3×10^{15} Hz when it makes transition from $n=2$ to $n=1$. The frequency of radiation emitted in transition from $n=3$ to $n=1$ is $\frac{x}{9} \times 10^{15}$ Hz, when $x =$ _____. **[1 Feb, 2024 (Shift-II)]**

11. According to Bohr's theory, the moment of momentum of an electron revolving in 4th orbit of hydrogen atom is:

[04 April, 2024 (Shift-II)]

(a) $8\frac{h}{\pi}$ (b) $\frac{h}{\pi}$ (c) $2\frac{h}{\pi}$ (d) $\frac{h}{2\pi}$

12. An electron rotates in a circle around a nucleus having positive charge Ze. Correct relation between total energy (E) of electron to its potential energy (U) is: **[05 April, 2024 (Shift-I)]**

(a) $E = 2U$ (b) $2E = 3U$ (c) $E = U$ (d) $2E = U$

13. The angular momentum of an electron in a hydrogen atom is proportional to : (Where r is the radius of orbit of electron)

[05 April, 2024 (Shift-II)]

(a) $\sqrt{r}$ (b) $\frac{1}{r}$ (c) r (d) $\frac{1}{\sqrt{r}}$

14. The shortest wavelength of the spectral lines in the Lyman series of hydrogen spectrum is 915 Å. The longest wavelength of spectral lines in the Balmer series will be _____ Å.

[05 April, 2024 (Shift-II)]

© TAKE CBSE X @ TEL EDUNET

15. The ratio of the shortest wavelength of Balmer series to the shortest wavelength of Lyman series for hydrogen atom is:
[06 April, 2024 (Shift-I)]
(a) 4 : 1 (b) 1 : 2 (c) 1 : 4 (d) 2 : 1

16. Radius of a certain orbit of hydrogen atom is 8.48 Å. If energy of electron in this orbit is E/x, then x = _____.
[06 April, 2024 (Shift-I)]
(Given $a_0 = 0.529$Å, E = energy of electron in ground state)

17. The longest wavelength associated with Paschen series is: (Given $R_H = 1.097 \times 10^7$ SI unit)
[06 April, 2024 (Shift-II)]
(a) 1.094×10^{-6} m (b) 2.973×10^{-6} m
(c) 3.646×10^{-6} m (d) 1.876×10^{-6} m

18. In Franck-Hertz experiment, the first dip in the current-voltage graph for hydrogen is observed at 10.2 V. The wavelength of light emitted by hydrogen atom when excited to the first excitation level is _____ nm.
(Given $hc = 1245$ eV nm, $e = 1.6 \times 10^{-19}$C).
[06 April, 2024 (Shift-II)]

19. In an alpha particle scattering experiment distance of closest approach for the α particle is 4.5×10^{-14} m. If target nucleus has atomic number 80, then maximum velocity of α-particle is _____ $\times 10^5$ m/s approximately.
($\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ SI unit, mass of α particle = 6.72×10^{-27} kg)
[08 April, 2024 (Shift-I)]

20. A hydrogen atom in ground state is given an energy of 10.2 eV. How many spectral lines will be emitted due to transition of electrons?
[09 April, 2024 (Shift-II)]
(a) 6 (b) 3 (c) 10 (d) 1

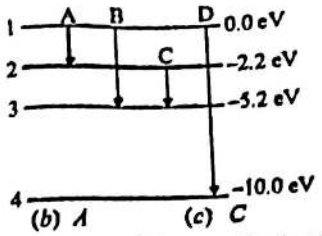
21. If the binding energy of ground state electron in a hydrogen atom is 13.6 eV, then, the energy required to remove the electron from the second excited state of Li^{2+} will be: $x \times 10^{-1}$ eV. The value of x is [31 Jan, 2023 (Shift-II)]

22. A light of energy 12.75 eV is incident on a hydrogen atom in its ground state. The atom absorbs the radiation and reaches to one of its excited states. The angular momentum of the atom in the excited state is $\frac{x}{\pi} \times 10^{-17}\ eVs$. The value of x is _____ (use $h = 4.14 \times 10^{-15}\ eVs, c = 3 \times 10^8\ ms^{-1}$). [1 Feb, 2023 (Shift-I)]

23. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. The number of spectral lines emitted will be:
[12 April, 2023 Shift-I]
(a) 2 (b) 1 (c) 3 (d) 4

24. The angular momentum for the electron in Bohr's orbit is L. If the electron is assumed to revolve in second orbit of hydrogen atom, then the change in angular momentum will be:
[10 April, 2023 Shift-I]
(a) $\frac{L}{2}$ (b) zero (c) L (d) $2L$

25. The energy levels of an atom is shown in figure. Which one of these transitions will result in the emission of a photon of wavelength 124.1 nm? Given ($h = 6.62 \times 10^{-34}$ Js) [25 Jan, 2023 (Shift-II)]



(a) B (b) A (c) C (d) D

26. An electron of a hydrogen like atom, having $Z = 4$, jumps from 4th energy state to 2nd energy state, The energy released in this process, will be:
(Given $Rch = 13.6eV$)
Where R = Rydberg constant
c = Speed of light in vacuum
h = Planck's constant [1 Feb, 2023 (Shift-II)]
(a) 13.6 eV (b) 10.5 eV (c) 3.4 eV (d) 40.8 eV

27. The radius of electron's second stationary orbit in Bohr's atom is R. The radius of 3rd orbit will be [31 Jan, 2023 (Shift-II)]
(a) $R/3$ (b) $2.25R$ (c) $3R$ (d) $9R$

28. A small particle of mass m moves in such a way that its potential energy $U = \frac{1}{2}m\omega^2 r^2$ where ω is constant and r is the distance of the particle from origin. Assuming Bohr's quantization of momentum and circular orbit, the radius of n^{th} orbit will be proportional to.
[6 April, 2023 (Shift-II)]
(a) $\sqrt{n}$ (b) n (c) n^2 (d) $\frac{1}{n}$

29. The radius of 2nd orbit of He^+ of Bohr's model is r_1 and that of fourth orbit of Be^{3+} is represented as r_2. Now the ratio r_2/r_1 is $x : 1$. The value of x is _____. [13 April, 2023 (Shift-I)]

30. The radius of fifth orbit of the Li^{++} is _____ $\times 10^{-12}$ m. Take : radius of hydrogen atom = 0.51Å [6 April, 2023 (Shift-I)]

31. $\sqrt{d_1}$ and $\sqrt{d_2}$ are the impact parameters corresponding to scattering angles 60° and 90° respectively, when an α particle is approaching a gold nucleus. For $d_1 = x\, d_2$, the value of x will be _____. [29 June, 2023 (Shift-I)]

32. Choose the correct option from the following options given below:
[24 June, 2022 (Shift-I)]
(a) In the ground state of Rutherford's model electrons are in stable equilibrium. While in Thomson's model electrons always experience a net – force.
(b) An atom has a nearly continuous mass distribution in a Rutherford's model but has a highly non-uniform mass distribution in Thomson's model
(c) A classical atom based on Rutherford's model is doomed to collapse.
(d) The positively charged part of the atom possesses most of the mass in Rutherford's model but not in Thomson's model.

33. The ratio for the speed of the electron in the 3rd orbit of He^+ to the speed of the electron in the 3rd orbit of hydrogen atom will be:
[25 June, 2022 (Shift-I)]
(a) 1:1 (b) 1:2 (c) 4:1 (d) 2:1

34. A hydrogen atom in its ground state absorbs 10.2 eV of energy. The angular momentum of electron of the hydrogen atom will increase by the value of:
(Given, Planck's constant = 6.6×10^{-34} Js).
[27 June, 2022 (Shift-I)]
(a) 2.10×10^{-34} Js (b) 1.05×10^{-34} Js
(c) 3.15×10^{-34} Js (d) 4.2×10^{-34} Js

@FAKE_GBSEX(OFFICIAL EDUNET

35. Given below are two statements:

Statement-I: In hydrogen atom, the frequency of radiation emitted when an electron jumps from lower energy orbit (E_1) to higher energy orbit (E_2), is given as $hf = E_1 - E_2$

Statement-II: The jumping of electron from higher energy orbit (E_2) to lower energy orbit E_1 is associated with frequency of radiation given as $f = (E_2 - E_1)/h$

This condition is Bohr's frequency condition.

In the light of the above statements, choose the correct answer from the options given below: **[27 June, 2022 (Shift-II)]**

(a) Both Statement-I and statement-II are true.
(b) Both Statement-I and statement-II are false.
(c) Statement-I is correct but statement-II is false.
(d) Statement-I is incorrect but statement-II is true.

36. The momentum of an electron revolving in n^{th} orbit is given by: (Symbols have their usual meanings) **[25 July, 2022 (Shift-I)]**

(a) $\frac{nh}{2\pi r}$ (b) $\frac{nh}{2r}$ (c) $\frac{nh}{2\pi}$ (d) $\frac{2\pi r}{nh}$

37. In Bohr's atomic model of hydrogen, let K, P and E are the kinetic energy, potential energy and total energy of the electron respectively. Choose the correct option when the electron undergoes transitions to a higher level: **[24 June, 2022 (Shift-II)]**

(a) All K, P and E increase.
(b) K decreases, P and E increase.
(c) P decreases, K and E increase.
(d) K increases, P and E decrease.

38. A particle of mass m moves in a circular orbit in a central potential field $U(r) = U_0 r^4$. If Bohr's quantization conditions are applied, radii of possible orbitals rn vary with $n^{\frac{1}{a}}$, where a is ____ .

[17 March, 2021 (Shift-II)]

39. If an electron is moving in the n^{th} orbit of the hydrogen atom, then its velocity (υ_n) for the n^{th} orbit is given as:

[17 March, 2021 (Shift-I)]

(a) $v_n \propto \frac{1}{n}$ (b) $\upsilon_n \propto n^2$ (c) $\upsilon_n \propto n$ (d) $v_n \propto \frac{1}{n^2}$

40. Imagine that the electron in a hydrogen atom is replaced by a muon (μ). The mass of muon particle is 207 times that of an electron and charge is equal to the charge of an electron. The ionization potential of this hydrogen atom will be **[18 March, 2021 (Shift-I)]**

(a) 13.6 eV (b) 2815.2 eV (c) 331.2 eV (d) 27.2 eV

41. Which level of the single ionized carbon has the same energy as the ground state energy of hydrogen atom? **[17 March, 2021 (Shift-I)]**

(a) 6 (b) 8 (c) 4 (d) 1

42. Consider a situation in which reverse biased current of a particular $P-N$ junction increase when it is exposed to a light of wavelength ≤ 621 nm. During this process, enhancement in carrier concentration takes place due to generation of hole – electron pairs. The value of band gap is nearly. **[22 July, 2021 (Shift-II)]**

(a) 1 eV (b) 4 eV (c) 0.5 eV (d) 2 eV

43. In a hydrogen atom the electron makes a transition from $(n+1)^{th}$ level to the n^{th} level. If $n >> 1$, the frequency of radiation emitted is proportional to **[2 Sep, 2020 (Shift-II)]**

(a) $\frac{1}{n}$ (b) $\frac{1}{n^2}$ (c) $\frac{1}{n^3}$ (d) $\frac{1}{n^4}$

44. Hydrogen ion and singly ionized helium atom are accelerated, from rest, through the same potential difference. The ratio of final speeds of hydrogen and helium ions is close to **[3 Sep, 2020 (Shift-II)]**

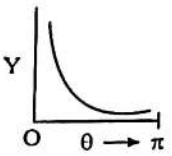
(a) 2 : 1 (b) 1 : 2 (c) 10 : 7 (d) 5 : 7

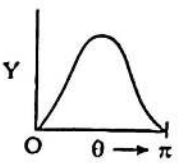
45. The graph which depicts the results of Rutherford gold foil experiment with α-particles is

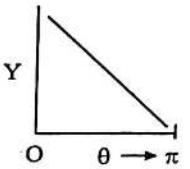
θ : Scattering angle

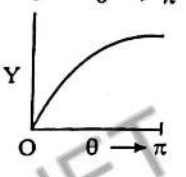
Y: Number of scattered a-particles detected

(Plots are schematic and not to scale) **[8 Jan, 2020 (Shift-I)]**

(a) 

(b) 

(c) 

(d) 

46. The time period of revolution of electron in its ground state orbit in a hydrogen atom is 1.6×10^{-16} s. The frequency of revolution of the electron in its first excited state (in s^{-1}) is:

[7 Jan, 2020 (Shift-I)]

(a) 6.2×10^{15} (b) 5.6×10^{12} (c) 7.8×10^{14} (d) 1.6×10^{14}

47. A particle of mass m moves in circular orbits with potential energy $U(r) = Fr$, where F is a positive constant and r is its distance from the origin. Its energies are calculated using the Bohr model. If the radius of the particle's orbit is denoted by R and its speed and energy are denoted by v and E, respectively, then for the n^{th} orbit (here h is the Planck's constant) **[JEE Adv, 2020]**

(a) $R \propto n^{1/3}$ and $v \propto n^{2/3}$ (b) $R \propto n^{2/3}$ and $v \propto n^{1/3}$

(c) $E = \frac{3}{2}\left(\frac{n^2h^2F^2}{4\pi^2 m}\right)^{1/3}$ (d) $E = 2\left(\frac{n^2h^2F^2}{4\pi^2 m}\right)^{1/3}$

48. A hydrogen atom, initially in the ground state is excited by absorbing a photon of wavelength 980 Å. The radius of the atom in the excited state, in terms of Bohr radius a_0, will ($hc = 12500$ eV – Å) **[11 Jan, 2019 (Shift-I)]**

(a) $25\,a_0$ (b) $9\,a_0$ (c) $16\,a_0$ (d) $4\,a_0$

49. A particle of mass m moves in a circular orbit in a central potential field $U(r) = \frac{1}{2}kr^2$. If Bohr's quantization conditions are applied, radii of possible orbits and energy levels vary with quantum number n as: **[12 Jan, 2019 (Shift-I)]**

(a) $r_n \propto \sqrt{n},\ E_n \propto n$ (b) $r_n \propto \sqrt{n},\ E_n \propto \frac{1}{n}$

(c) $r_n \propto n, E_n \propto n$ (d) $r_n \propto n^2, E_n \propto \frac{1}{n^2}$

50. A He^+ ion is in its first excited state. Its ionization energy is:

[9 April, 2019 (Shift-II)]

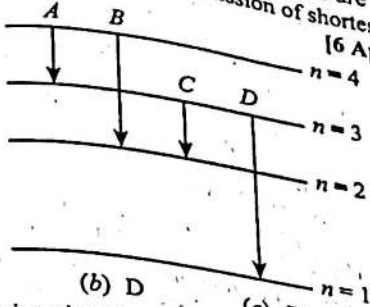
(a) 6.04 eV (b) 13.60 eV (c) 54.40 eV (d) 48.36 eV

51. Speed of an electron in Bohr's 7^{th} orbit for Hydrogen atom is 3.6×10^6 m/s. The corresponding speed of the electron in 3^{rd} orbit, in m/s is: **[8 Jan, 2023 (Shift-I)]**

(a) (1.8×10^6) (b) (7.5×10^6) (c) (3.6×10^6) (d) (8.4×10^6)

@JEE CBSE X @JEENET

52. The energy levels of an hydrogen atom are shown below. The transition corresponding to emission of shortest wavelength is **[6 April, 2023 (Shift-I)]**



(a) C (b) D (c) B (d) A

53. A photon is emitted in transition from $n = 4$ to $n = 1$ level in hydrogen atom. The corresponding wavelength for this transition is (given, $h = 4 \times 10^{-15}$ eVs): **[24 Jan, 2023 (Shift-II)]**

(a) 94.1 nm (b) 941 nm (c) 97.4 nm (d) 99.3 nm

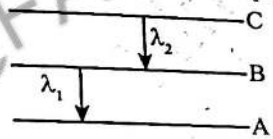
54. A monochromatic light is incident on a hydrogen sample in ground state. Hydrogen atoms absorb a fraction of light and subsequently emit radiation of six different wavelengths. The frequency of incident light is $x \times 10^{15}$ Hz. The value of x is . (Given $h = 4.25 \times 10^{-15}$ eVs) **[11 April, 2023 (Shift-I)]**

55. An atom absorbs a photon of wavelength 500 nm and emits another photon of wavelength 600 nm. The net energy absorbed by the atom in this process is $n \times 10^{-4} eV$. The value of n is [Assume the atom to be stationary during the absorption and emission process] (Take $h = 6.6 \times 10^{-34}$ Js and $c = 3 \times 10^8$ m/s). **[13 April, 2023 (Shift-II)]**

56. The ratio of wavelength of spectral lines H_α and H_β in the Balmer series is $\frac{x}{20}$. The value of x is **[8 April, 2023 (Shift-II)]**

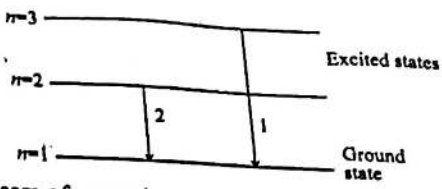
57. If 917 Å be the lowest wavelength of Lyman series then the lowest wavelength of Balmer series will be ____ Å. **[10 April, 2023 (Shift-II)]**

58. As per given figure A, B and C are the first, second and third excited energy level of hydrogen atom respectively. If the ratio of the two wavelengths $\left(i.e. \frac{\lambda_1}{\lambda_2}\right)$ is $\frac{7}{4n}$, then the value of n will be **[15 April, 2023 (Shift-I)]**



59. The wavelength of the radiation emitted is λ_0 when an electron jumps from the second excited state to the first excited state of hydrogen atom. If the electron jumps from the third excited state to the second orbit of the hydrogen atom, the wavelength of the radiation emitted will be $\frac{20}{x}\lambda_0$. The value of x is _____. **[25 Jan, 2023 (Shift-I)]**

60. For hydrogen atom, λ_1 and λ_2 are the wavelengths corresponding to the transitions 1 and 2 respectively as shown in the figure. The ratio of λ_1 and λ_2 is $\frac{x}{32}$. The value of x is _____. **[31 Jan, 2023 (Shift-I)]**



61. A beam of monochromatic light is used to excite the electron in Li^{++} from the first orbit to the third orbit. The wavelength of monochromatic light is found to be $x \times 10^{-10}$ m . The value of x is [Given $hc = 1242$ eV nm] **[27 June, 2022 (Shift-I)]**

62. Find the ratio of energies of photos produced due to transition of an electron of hydrogen atom from its (i) second permitted energy level to the first level, and (ii) the highest permitted energy level to the first permitted level. **[29 July, 2022 (Shift-I)]**

(a) 3 : 4 (c) 1 : 4 (b) 4 : 3 (d) 4 : 1

63. Hydrogen atom from excited state comes to the ground state by emitting a photon of wavelength λ. The value of principal quantum number 'n' of the excited state will be: (R: Rydberg constant) **[25 July, 2022 (Shift-II)]**

(a) $\sqrt{\frac{\lambda R}{\lambda - 1}}$ (b) $\sqrt{\frac{\lambda R}{\lambda R - 1}}$ (c) $\sqrt{\frac{\lambda}{\lambda R - 1}}$ (d) $\sqrt{\frac{\lambda R^2}{\lambda R - 1}}$

64. $\frac{x}{x+4}$ is the ratio of energies of photons produced due to transition of an electron of hydrogen atom from its:

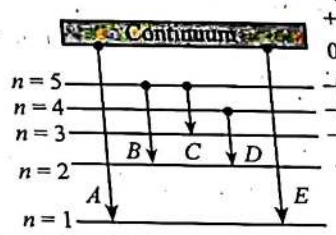
(i) third permitted energy level to the second level and

(ii) the highest permitted energy level to the second permitted level.

The value of x will be _____. **[25 July, 2022 (Shift-II)]**

65. In the hydrogen spectrum, λ be the wavelength of first transition line of Lyman series. The wavelength difference will be "$a\lambda$" between the wavelength of 3rd transition line of Paschen series and that of 2nd transition line of Balmer series where $a =$ _____. **[26 July, 2022 (Shift-I)]**

66. In the given, figure, the energy levels of hydrogen atom have been shown along with some transitions marked A, B, C, D and E. The transitions A, B and C respectively represent: **[24 Feb, 2021 (Shift-I)]**



(a) The series limit of Lyman series, second member of Balmer series and second member of Paschen series.

(b) The first member of the Lyman series, third member of Balmer series and second member of Paschen series.

(c) The ionization potential of hydrogen, second member of Balmer series and third member of Paschen series.

(d) The series of Lyman series, third member of Balmer series and second member of Paschen series.

67. According to Bohr atom model, in which of the following transitions will the frequency be maximum? **[24 Feb, 2021 (Shift-II)]**

(a) $n = 3$ to $n = 2$ (b) $n = 4$ to $n = 3$
(c) $n = 2$ to $n = 1$ (d) $n = 5$ to $n = 4$

@FAKE_JOSE_X_GRAVEDUNET

68. The atomic hydrogen emits a line spectrum consisting of various series. Which series of hydrogen atomic spectra is lying in the visible region? **[17 March, 2021 (Shift-II)]**
(a) Paschen series (b) Balmer series
(c) Lyman series (d) Brackett series

69. A particular hydrogen like ion emits radiation of frequency 2.92×10^{15} Hz when it makes transition from $n = 3$ to $n = 1$. The frequency in Hz of radiation emitted in transition from $n = 2$ to $n = 1$ will be: **[26 Aug, 2021 (Shift-I)]**
(a) 2.46×10^{15} (b) 4.38×10^{15} (c) 6.57×10^{15} (d) 0.44×10^{15}

70. The wavelength of the photon emitted by a hydrogen atom when an electron makes a transition from $n = 2$ to $n = 1$ state is: **[25 Feb, 2021 (Shift-II)]**
(a) 121.8 nm (b) 194.8 nm (c) 490.7 nm (d) 913.3 nm

71. If λ_1 and λ_2 are the wavelengths of the third member of Lyman and first member of the Paschen series respectively, then the value of $\lambda_1 : \lambda_2$ is: **[26 Feb, 2021 (Shift-I)]**
(a) 1 : 3 (b) 7 : 108 (c) 1 : 9 (d) 7 : 135

72. The recoil speed of a hydrogen atom after it emits a photon in going from $n = 5$ state to $n = 1$ state will be: **[26 Feb, 2021 (Shift-II)]**
(a) 4.17 m/s (b) 2.19 m/s (c) 4.34 m/s (d) 3.25 m/s

73. X different wavelengths may be observed in the spectrum from a hydrogen sample if the atoms are excited to states with principal quantum number $n = 6$? The value of X is _____. **[27 Aug, 2021 (Shift-II)]**

74. The first three spectral of H-atom in the Balmer series are given λ_1, λ_2, λ_3 considering the Bohr atomic model, the wave lengths of first and third spectral lines $\left(\frac{\lambda_1}{\lambda_3}\right)$ are related by a factor of approximately 'x' $\times 10^{-1}$. **[16 March, 2021 (Shift-I)]**

75. Which of the following statement(s) is(are) correct about the spectrum of hydrogen atom? **[JEE Adv, 2021]**
(a) The ratio of the longest wavelength to the shortest wavelength in Balmer series is 9/5
(b) There is an overlap between the wavelength ranges of Balmer and Paschen series
(c) The wavelength of Lyman series are given by $\left(1+\frac{1}{m^2}\right)\lambda_0$, where λ_0 is the shortest wavelength of Lyman series and m is an integer
(d) The wavelength ranges of Lyman and Balmer series do not overlap

76. The energy required to ionise a hydrogen like ion in its ground state is 9 Rydbergs. What is the wavelength of the radiation emitted when the electron in this ion jumps from the second excited state to the ground state: **[9 Jan, 2020 (Shift-II)]**
(a) 11.4 nm (b) 24.2 nm (c) 35.8 nm (d) 8.6 nm

77. The first member of the Balmer series of hydrogen atom has a wavelength of 6561 Å. The wavelength of the second member of the Balmer series (in nm) is _____. **[8 Jan, 2020 (Shift-II)]**

78. In the line spectra of hydrogen atom, difference between the largest and the shortest wavelengths of the Lyman series is 304Å. The corresponding difference for the Paschan series in Å is: _____. **[4 Sep, 2020 (Shift-I)]**

79. An excited He^+ ion emits two photons in succession, with wavelengths 108.5 nm and 30.4 nm, in making a transition to ground state. The quantum number n, corresponding to its initial excited state is (for photon of wavelength λ, energy $E = \frac{1240eV}{\lambda(\text{in nm})}$:) **[12 April, 2019 (Shift-I)]**
(a) $n = 4$ (b) $n = 6$ (c) $n = 5$ (d) $n = 7$

80. In Li^{++}, electron in first Bohr orbit is excited to a level by a radiation of wavelength λ. When the ion gets deexcited to the ground state in all possible ways(including intermediate emission) a total of six spectral lines are observed. What is the value of λ? (Given: $h = 6.63 \times 10^{-34}$ Js; $c = 3 \times 10^8$ ms^{-1}) **[10 April, 2019 (Shift-II)]**
(a) 10.8 nm (b) 11.4 nm (c) 9.4 nm (d) 12.3 nm

81. Radiation coming from transition $n = 2$ to $n = 1$ of hydrogen atoms fall of He^+ ions in $n = 1$ and $n = 2$ states. The possible transition of helium ions as they absorb energy from the radiation is: **[8 April, 2019 (Shift-I)]**
(a) $n = 1 \rightarrow n = 4$ (b) $n = 2 \rightarrow n = 4$
(c) $n = 2 \rightarrow n = 5$ (d) $n = 2 \rightarrow n = 3$

82. Taking the wavelength of first Balmer line in hydrogen spectrum ($n = 3$ to $n = 2$) as 660 nm, the wavelength of the 2nd Balmer line ($n = 4$ to $n = 2$) will be **[9 April, 2019 (Shift-I)]**
(a) 889.2 nm (b) 642.7 nm (c) 488.9 nm (d) 388.9 nm

83. The electron in a hydrogen atom first jumps from the third excited state to the second excited state and subsequently to the first excited state. The ratio of the respective wavelengths, λ_1/λ_2, of the photons emitted in this process is: **[12 April, 2019 (Shift-II)]**
(a) 20/7 (b) 7/5 (c) 9/7 (d) 27/5

84. In a hydrogen like atom, when an electron jumps from the M-shell to the L-shell the wavelength of emitted radiation is λ. If an electron jumps from N-shell to the L-shell the wavelength of emitted radiation will be: **[11 Jan, 2019 (Shift-II)]**
(a) $\frac{27}{20}\lambda$ (b) $\frac{16}{25}\lambda$ (c) $\frac{25}{16}\lambda$ (d) $\frac{20}{27}\lambda$

85. A free hydrogen atom after absorbing a photon of wavelength λ_a gets excited from the state $n = 1$ to the state $n = 4$. Immediately after that the electron jumps to $n = m$ state by emitting a photon of wavelength λ_e. Let the chang in momentum of atom due to the absorption and the emission are Δp_a and Δp_e, respectively. If $\lambda_a/\lambda_e = \frac{1}{5}$. Which of the option(s) is/are correct? **[JEE Adv, 2019]**
[Use $hc = 1242$ eV nm; 1 nm = 10^{-9} m, h and c are Planck's constant and speed of light, respectively]
(a) $\lambda_e = 418$ nm
(b) The ratio of kinetic energy of the electron in the state n = m to the state $n = 1$ is $\frac{1}{4}$
(c) $m = 2$
(d) $\Delta p_a/\Delta p_e = \frac{1}{2}$

86. An excited He^+ ion emits two photons in succession, with wavelengths 108.5 nm and 30.4 nm, in making a transition to ground state. The quantum number n, corresponding to its initial excited state is (for photon of wavelength λ, energy $E = \frac{1240eV}{\lambda(\text{in nm})}$:) **[12 April, 2019 (Shift-I)]**
(a) $n = 4$ (b) $n = 6$
(c) $n = 5$ (d) $n = 7$

CRACK CBSE X @RAJ_EDUNITE

Atomic Collision

87. When a hydrogen atom going from $n = 2$ to $n = 1$ emits a photon, its recoil speed is $\frac{x}{5}$ m/s. Where $x =$ _____. (Use: mass of hydrogen atom $= 1.6 \times 10^{-27}$ kg)
[29 Jan, 2024 (Shift-I)]

88. A hydrogen atom changes its state from $n = 3$ to $n = 2$. Due to recoil, the percentage change in the wavelength of emitted light is approximately 1×10^{-n}. The value of n is _____.
[Given $Rhc = 13.6$ eV, $hc = 1242$ eV nm, $h = 6.6 \times 10^{-34}$ J s, mass of the hydrogen atom $= 1.6 \times 10^{-27}$ kg]
[04 April, 2024 (Shift-I)]

89. A free electron of 2.6 eV energy collides with a H^+ ion. This results in the formation of a hydrogen atom in the first excited state and a photon is released. Find the frequency of the emitted photon. ($h = 6.6 \times 10^{-34}$ Js)
[31 Aug, 2021 (Shift-II)]
(a) 0.19×10^{15} MHz (b) 1.45×10^{9} MHz
(c) 1.45×10^{16} MHz (d) 9.0×10^{27} MHz

90. A particle of mass $200 MeV/c^2$ collides with a hydrogen atom at rest. Soon after the collision the particle comes to rest, and the atom recoils and goes to its first excited state. The initial kinetic energy of the particle (in eV) is $\frac{N}{4}$. The value of N is: (Given the mass of the hydrogen atom to be 1 GeV/c^2)
[5 Sep, 2020 (Shift-I)]

91. An ideal gas is enclosed in a cylinder at pressure of 2 atm and temperature, 300 K. The mean time between two successive collisions is 6×10^{-8} s. If the pressure is doubled and temperature is increased to 500 K, the mean time between two successive collisions will be close to :
[12 Jan, 2019 (Shift-II)]
(a) 2×10^{-7} s (b) 4×10^{-8} s
(c) 0.5×10^{-8} s (d) 3×10^{-6} s

92. An alpha-particle of mass m suffers 1-deminsional elastic collision with a nucleus at rest of unknown mass. It is scattered directly backwards losing, 64% of its initial kinetic energy. The mass of the nucleus is:
[12 Jan, 2019 (Shift-II)]
(a) 2 m (b) 3.5 m (c) 1.5 m (d) 4 m

X-ray

93. The waves emitted when a metal target is bombarded with high energy electrons are
[8 April, 2023 (Shift-II)]
(a) Microwaves (b) X-rays
(c) Infrared rays (d) Radio Waves

94. The $K_\alpha - X$ ray of molybdenum has wavelength 0.071 nm. If the energy of a molybdenum atom with a K electron knocked out is 27.5 ke$V$, the energy of this atom when an L electron is knocked out will be _____ ke V. (Round off to the nearest integer)
[27 July, 2021 (Shift-II)]
[$h = 4.14 \times 10^{-15}$ eVs, $c = 3 \times 10^{8}$ ms^{-1}]

95. In an X-ray tube, electrons emitted from a filament (cathode) carrying current I hit a target (anode) at a distance d from the cathode. The target is kept at a potential V higher than the cathode resulting in emission of continuous and characteristic X-rays. If the filament current I is decreased to $\frac{I}{2}$, the potential difference V is increased to $2V$, and the separation distance d is reduced to $\frac{d}{2}$, then
[JEE Adv, 2020]
(a) The cut-off wavelength will reduce to half, and the wavelengths of the characteristic X-rays will remain the same
(b) The cut-off wavelength as well as the wavelengths of the characteristic X-rays will remain the same
(c) The cut-off wavelength will reduce to half, and the intensities of all the X-rays will decrease
(d) The cut-off wavelength will become two times larger, and the intensity of all the X-rays will decrease

@FAKE_CBEX @RAJ_EDU_NET

JEE-Advanced

Atoms

Single Correct

1. The electric potential between a proton and an electron is given by $V = V_0 \ln \frac{r}{r_0}$, where r_0 is a constant. Assuming Bohr's model to be applicable, write variation of r_n with n, n being the principal quantum number.
(IIT-JEE 2003)
(a) $r_n \propto n$ (b) $r_n \propto \frac{1}{n}$ (c) $r_n \propto n^2$ (d) $r_n \propto \frac{1}{n^2}$

2. If the atom $_{100}Fm^{257}$ follows the Bohr's model and the radius of last orbit of $_{100}Fm^{257}$ is n times the Bohr radius, then find n
(IIT-JEE 2003)
(a) 100 (b) 200 (c) 4 (d) ¼

3. Imagine an atom made up of proton and a hypothetical particle of double the mass of the electron but having the same charge as the electron. Apply the Bohr atom model and consider all possible transitions of this hypothetical particle to the first excited level. The longest wavelength photon that will be emitted has wavelength λ (given in terms of the Rydberg constant R for the hydrogen atom) equal to
(IIT-JEE 2000)
(a) 9/5R (b) 36/5R (c) 18/5R (d) 4/R

4. As per Bohr model, the minimum energy (in eV) required to remove an electron from the ground state of doubly ionized Li atom ($Z = 3$) is **(IIT-JEE 1997)**

(a) 1.51 (b) 13.6 (c) 40.8 (d) 122.4

Multiple Correct

5. A particle of mass m moves in circular orbits with potential energy $U(r)=Fr$, where F is a positive constant and r is its distance from the origin. Its energies are calculated using the Bohr model. If the radius of the particle's orbit is denoted by R and its speed and energy are denoted by v and E, respectively, then for the n^{th} orbit (here h is the Planck's constant)

C-16.18 W-24.48 UA-40.74 PC-18.59 (JEE Adv. 2020)

(a) $R \propto n^{1/3}$ and $v \propto n^{2/3}$ (b) $R \propto n^{2/3}$ and $v \propto n^{1/3}$

(c) $E = \frac{3}{2}\left(\frac{n^2h^2F^2}{4\pi^2 m}\right)^{1/3}$ (d) $E = 2\left(\frac{n^2h^2F^2}{4\pi^2 m}\right)^{1/3}$

6. Highly excited states for hydrogen-like atoms (also called Rydberg states) with nuclear charge Ze are defined by their principle quantum number n, where $n >> 1$. Which of the following statement(s) is/are true? **C-3.14 W-17.83 UA-48.87 PC-30.17 (JEE Adv. 2016)**

(a) Relative change in the radii of two consecutive orbitals does not depend on Z

(b) Relative change in the radii of two consecutive orbitals varies as $1/n$

(c) Relative change in the energy of two consecutive orbitals varies as $1/n^3$

(d) Relative change in the angular momenta of two consecutive orbitals varies as $1/n$

7. The radius of the orbit of an electron in a Hydrogen-like atom is $4.5a_0$ where a_0 is the Bohr radius. Its orbital angular momentum is $\frac{3h}{2\pi}$. It is given that h is Planck constant and R is Rydberg constant. The possible wavelength (s), when the atom de-excites, is/are

C-26.07 W-29.49 UA-44.44 (JEE Adv. 2013)

(a) $\frac{9}{32R}$ (b) $\frac{9}{16R}$ (c) $\frac{9}{5R}$ (d) $\frac{4}{3R}$

8. In the Bohr model of the hydrogen atoms **(IIT-JEE 1984)**

(a) the radius of the nth orbit is proportional n^2.

(b) the total energy of the electron in the n^{th} orbit is inversely proportional to n.

(c) the angular momentum of the electron in an orbit is an integral multiple of h/π.

(d) the magnitude of the potential energy of the electron in any orbit is greater than its kinetic energy.

Comprehension Based/Passage Based

Passage 1

The key feature of Bohr's theory of spectrum of hydrogen atom is the quantisation of angular momentum when an electron is revolving around a proton. We will extend this to a general rotational motion to find quantised rotational energy of a diatomic molecule assuming it to be rigid. The rule to be applied is Bohr's quantisation condition.

9. A diatomic molecule has moment of inertia I. By Bohr's quantization condition its rotational energy in the nth level ($n = 0$ is not allowed) is **(IIT-JEE 2010)**

(a) $\frac{1}{n^2}\left(\frac{h^2}{8\pi^2 I}\right)$ (b) $\frac{1}{n}\left(\frac{h^2}{8\pi^2 I}\right)$ (c) $n\left(\frac{h^2}{8\pi^2 I}\right)$ (d) $n^2\left(\frac{h^2}{8\pi^2 I}\right)$

10. It is found that the excitation frequency from ground to the first excited state of rotation for the CO molecule is close to $\frac{4}{\pi} \times 10^{11}$ Hz. Then the moment of inertia of CO molecule about its centre of mass is close to (Take $h = 2\pi \times 10^{-34}$ J-s) **(IIT-JEE 2010)**

(a) 2.76×10^{-46} kg-m^2 (b) 1.87×10^{-46} kg-m^2

(c) 4.67×10^{-47} kg-m^2 (d) 1.17×10^{-47} kg-m^2

11. In a CO molecule, the distance between C (mass = 12 amu) and O (mass = 16 amu), where 1 amu = $\frac{5}{3} \times 10^{-27}$ kg, is close to **(IIT-JEE 2010)**

(a) 2.4×10^{-10} m (b) 1.9×10^{-10} m

(c) 1.3×10^{-10} m (d) 4.4×10^{-11} m

Passage 2

When a particle is restricted to move along x-axis between $x = 0$ and $x = a$, where a is of nanometer dimension, its energy can take only certain specific values. The allowed energies of the particle moving in such a restricted region, correspond to the formation of standing waves with nodes at its ends $x = 0$ and $x = a$. The wavelength of this standing wave is related to the linear momentum p of the particle according to the de-Broglie relation. The energy of the particle of mass m is related to its linear momentum as $E = \frac{p^2}{2m}$. Thus, the energy of the particle can be denoted by a quantum number n taking values 1, 2, 3, ...($n = 1$, called the ground state) corresponding to the number of loops in the standing wave. Use the model described above to answer the following three questions for a particle moving in the line $x = 0$ to $x = a$. [Take $h = 6.6 \times 10^{-34}$ Js and $e = 1.6 \times 10^{-19}$ C]

12. The allowed energy for the particle for a particular value of n is proportional to **(IIT-JEE 2009)**

(a) a^{-2} (b) $a^{-3/2}$ (c) a^{-1} (d) a^2

13. If the mass of the particle is $m = 1.0 \times 10^{-30}$ kg and $a = 6.6$ nm, the energy of the particle in its ground state is closest to **(IIT-JEE 2009)**

(a) 0.8 meV (b) 8 meV (c) 80 meV (d) 800 meV

14. The speed of the particle that can take discrete values is proportional to **(IIT-JEE 2009)**

(a) $n^{-3/2}$ (b) n^{-1} (c) $n^{1/2}$ (d) n

Passage 3

In a mixture of $H - He^+$ gas (He^+ is singly ionized He atom), H atoms and He^+ ions are excited to their respective first excited states. Subsequently, H atoms transfer their total excitation energy to He^+ ions (by collisions). Assume that the Bohr model of atoms is exactly valid.

15. The quantum number n of the state finally populated in He^+ ions is **(IIT-JEE 2008)**

(a) 2 (b) 3 (c) 4 (d) 5

@FAKE_CBSE_X@RAJ_EDUNET

(a) 6.5×10^{-7} m (b) 5.6×10^{-7} m
(c) 4.8×10^{-7} m (d) 4.0×10^{-7} m

17. The ratio of the kinetic energy of the $n = 2$ electron for the H atom to that of He^+ ion is (IIT-JEE 2008)
(a) 1/4 (b) 1/2 (c) 1 (d) 2

Numerical Types/Integer Types

18. An electron in an excited state of Li^{2+} ion has angular momentum $\frac{3h}{2\pi}$. The de Broglie wavelength of the electron in this state is $p\pi a_0$ (where a_0 is the Bohr radius). The value of p is (JEE Adv. 2015)

Fill in the Blanks

19. In the Bohr model of the hydrogen atom, the ratio of the kinetic energy to the total energy of the electron in a quantum state n is ..... . (IIT-JEE 1992)

Subjective

20. Consider a hydrogen atom with its electro in the n^{th} orbital. An electromagnetic radiation of wavelength 90 nm is used to ionize the atom. If the kinetic energy of the ejected electron is 10.4eV, then the value of n is ($hc = 1242eV_{nm}$) (JEE Adv. 2015)

21. A hydrogen-like atom (described by the Bohr's model) is observed to emit six wavelengths, originating from all possible transitions between a group of levels. These levels have energies between –0.85eV and –0.544eV (including both these values).

(IIT-JEE 2002)

(a) Find the atomic number of the atom.
(b) Calculate the smallest wavelength emitted in these transitions.
(Take $hc = 1240eV - nm$, ground state energy of hydrogen atom $= -13.6eV$)

22. A hydrogen-like atom (described by the Bohrs model) is observed to emit six wavelengths, originating from all possible transitions between a group of levels. These levels have energies between –0.85 eV and –0.544 eV (including both these values).

(IIT-JEE 2002)

(a) Find the atomic number of the atom.
(b) Calculate the smallest wavelength emitted in these transitions.
(Take hc = 1240 eV-nm, ground state energy of hydrogen atom = –13.6 eV)

23. A single electron orbits around a stationary nucleus of charge +Ze. Where Z is a constant and e is the magnitude of the electronic charge. It requires 47.2 eV to excite the electron from the second Bohr orbit to the third Bohr orbit. (IIT-JEE 1981)
Find
(a) the value of Z.
(b) the energy required to excite the electron from the third to the fourth Bohr orbit.
(c) the wavelength of the electromagnetic radiation required to remove the electron from the first Bohr orbit to infinity.
(d) the kinetic energy, potential energy and the angular momentum of the electron in the first Bohr orbit.
(e) the radius of the first Bohr orbit.

(The Ionization energy of hydrogen atom =13 6 . eV, Bohr radius = 5.3×10^{-11} m, velocity of light = 3×10^8 m/s. Planck's constant = 6.6×10^{-34} J-s).

24. The Ionization energy of a hydrogen like Bohr atom is 4 rydberg. (IIT-JEE 1984)
(a) What is the wavelength of the radiation emitted when the electron jumps from the first excited state to the ground state?
(b) What is the radius of the first orbit for this atom?

25. A gas of identical hydrogen-like atoms has some atoms in the lowest (ground) energy level A and some atoms in a particular upper (excited) energy level B and there are no atoms in any other energy level. The atoms of the gas make the transition to a higher energy level by absorbing monochromatic light of photon energy 2.7eV. Subsequently, the atoms emit radiation of only six different energy photons. Some of the emitted photons have an energy of 2.7 eV, some have more energy and some less than 2.7 eV.(IIT-JEE 1989)
(a) Find the principal quantum number of the initially excited level B.
(b) Find the ionization energy for the gas atoms.
(c) Find the maximum and the minimum energies of the emitted photons.

26. A particle of charge equal to that of an electron – e, and mass 208 times of the mass of the electron (called a mu-meson) moves in a circular orbit around a nucleus of charge +3e. (Take the mass of the nucleus to be infinite). Assuming that the Bohr model of the atom is applicable to this system, (IIT-JEE 1988)
(a) derive an expression for the radius of the n th Bohr orbit.
(b) find the value of n for which the radius of the orbit is approximately the same as that of the first Bohr orbit for the hydrogen atom.
(c) find the wavelength of the radiation emitted when the mu-meson jumps from the third orbit to the first orbit. (Rydberg's constant = 1.097×10^7 m^{-1})

Hydrogen Spectrum

Single Correct

27. If λ_{Cu} is the wavelength of K_α, X-ray line of copper (atomic number 29) and λ_{Mo} is the wavelength of the K_α, X-ray line of molybdenum (atomic number 42), then the ratio $\lambda_{Cu}/\lambda_{Mo}$ is close to
C-24.9 W-38.78 UA-36.33 (JEE Adv. 2014)
(a) 1.99 (b) 2.14 (c) 0.50 (d) 0.48

28. The largest wavelength in the ultraviolet region of the hydrogen spectrum is 122 nm. The smallest wavelength in the infrared region of the hydrogen spectrum (to the nearest integer) is.
(IIT-JEE 2007)
(a) 802 nm (b) 823 nm (c) 1882 nm (d) 1648 nm

29. K_α wavelength emitted by an atom of atomic number $Z = 11$ is λ. Find the atomic number for an atom that emits K_α radiation with wavelength 4λ (IIT-JEE 2005)
(a) $Z = 6$ (b) $Z = 4$ (c) $Z = 11$ (d) $Z = 44$

@PACE_OF_X@RVLEGNET

30. A hydrogen atom and a Li^{2+} ion are both in the second excited state. If l_H and l_{Li} are their respective electronic angular momenta, and E_H and E_{Li} their respective energies, then **(IIT-JEE 2002)**

(a) $l_H > l_{Li}$ and $|E_H| > |E_{Li}|$ (b) $l_H = l_{Li}$ and $|E_H| < |E_{Li}|$

(c) $l_H = l_{Li}$ and $|E_H| > |E_{Li}|$ (d) $l_H < l_{Li}$ and $|E_H| < |E_{Li}|$

31. The transition from the state $n = 4$ to $n = 3$ in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition **(IIT-JEE 2001)**

(a) $2 \rightarrow 1$ (b) $3 \rightarrow 2$ (c) $4 \rightarrow 2$ (d) $5 \rightarrow 4$

32. The electron in a hydrogen atom makes a transition from an excited state to the ground state. Which of the following statement is true? **(IIT-JEE 2000)**

(a) Its kinetic energy increases and its potential and total energy decreases

(b) Its kinetic energy decreases, potential energy increases and its total energy remains the same

(c) Its kinetic and total energy decreases and its potential energy increases

(d) Its kinetic, potential and total energy decreases

33. In hydrogen spectrum, the wavelength of H_α line is 656 nm; whereas in the spectrum of a distant galaxy H_α line wavelength is 706 nm. Estimated speed of galaxy with respect to earth is **(IIT-JEE 1999)**

(a) 2×10^8 m/s (b) 2×10^7 m/s

(c) 2×10^6 m/s (d) 2×10^5 m/s

34. Consider the spectral line resulting from the transition $n = 2 \rightarrow n = 1$ in the atoms and ions given below. The shortest wavelength is produced by **(IIT-JEE 1983)**

(a) hydrogen atom (b) deuterium atom

(c) singly ionised helium (d) doubly ionised lithium

35. Beta rays emitted by a radioactive material are **(IIT-JEE 1983)**

(a) electromagnetic radiations

(b) the electrons orbiting around the nucleus

(c) charged particles emitted by the nucleus

(d) neutral particles

36. The equation;

$4\,{}_1^1H \longrightarrow {}_2^4He^{2+} + 2e^- +$ 26MeV represents **(IIT-JEE 1983)**

(a) β-decay (b) γ-decay (c) fusion (d) fission

Multiple Correct

37. Which of the following statement(s) is/are correct about the spectrum of hydrogen atom?

C-22.02 W-37.91 UA-16.72 PC-23.34 (JEE Adv. 2021)

(a) The ratio of the longest wavelength to the shortest wavelength in Balmer series is 9/5

(b) There is an overlap between the wavelength ranges of Balmer and Paschen series

(c) The wavelength of Lyman series are given by $\left(1+\frac{1}{m^2}\right)\lambda_0$, where λ_0 is the shortest wavelength of Lyman series and m is an integer

(d) The wavelength ranges of Lyman and Balmer series do not overlap

38. A free hydrogen atom after absorbing a photon of wavelength λ_a gets excited from the state $n = 1$ to the state $n = 4$. Immediately after that the electron jumps to $n = m$ state by emitting a photon of wavelength λ_e. Let the change in momentum of atom due to the absorption and the emission are Δp_a and Δp_e, respectively. If $\lambda_a/\lambda_e = \frac{1}{5}$. Which of the option(s) is/are correct? [Use $hc = 1242$ eV nm; 1 nm $= 10^{-9}$ m, h and c are Planck's constant and speed of light, respectively]

C-26.93 W-34.16 UA-30.82 PC-8.09 (JEE Adv. 2019)

(a) $\lambda_a = 418\ nm$

(b) The ratio of kinetic energy of the electron in the state $n = m$ to the state $n = 1$ is $\frac{1}{4}$

(c) $m = 2$

(d) $\Delta p_a/\Delta p_e = \frac{1}{2}$

Numerical Types/Integer Types

39. Consider a hydrogen-like ionised atom with atomic number Z with a single electron. In the emission spectrum of this atom, the photon emitted in the $n = 2$ to $n = 1$ transition has energy 74.8 eV higher than the photon emitted in the $n = 3$ to $n = 2$ transition. The ionisation energy of the hydrogen atom is 13.6 eV. The value of Z is .....

C-41.64 W-48.98 UA-9.38 (JEE Adv. 2018)

40. An electron in a hydrogen atom undergoes a transition from an orbit with quantum number n_i to another with quantum number n_f. v_i and v_f are respectively the initial and final potential energies of the electron. If $\frac{v_i}{v_f} = 625$, then the smallest possible n_f is

C-45.5 W-51.05 UA-3.45 (JEE Adv. 2017)

41. A hydrogen atom in its ground state is irradiated by light of wavelength 970Å. Taking $hc/e = 1.237 \times 10^{-6}$ eVm and the ground state energy of hydrogen atom as -13.6 eV, the number of lines present in the emission spectrum is

C-20.24 W-75.33 UA-4.44 (JEE Adv. 2016)

Fill in the Blanks

42. The wavelength of the characteristic X-ray Ka line emitted by a hydrogen like element is 0.32Å. The wavelength of the Kb line emitted by the same element will be ..... . **(IIT-JEE 1990)**

43. The recoil speed of a hydrogen atom after it emits a photon in going from $n = 5$ state to $n = 1$ state is ..... m/s. **(IIT-JEE 1997)**

Subjective

44. Wavelengths belonging to Balmer series lying in the range of 450 nm to 750 nm were used to eject photoelectrons from a metal surface whose work function is 2.0 eV. Find (in eV) the maximum kinetic energy of the emitted photoelectrons. (Take hc = 1242 eV nm.) **(IIT-JEE 2004)**

45. A hydrogen like atom of atomic number Z is in an excited state of quantum number $2n$. It can emit a maximum energy photon of $204eV$. If it makes a transition to quantum state n, a photon of energy $40.8eV$ is emitted. Find n, Z and the ground state energy (in eV) of this atom. Also, calculate the minimum energy (in eV) that can be emitted by this atom during de-excitation. Ground state energy of hydrogen atom is $-13.6eV$. **(IIT-JEE 2000)**

@FAKE_CBSE_X@RAU_EDUNET

46. A hydrogen like atom (atomic number Z) is in a higher excited state of quantum number n. The excited atom can make a transition to the first excited state by successively emitting two photons of energy 10.2 eV and 17.0 eV respectively. Alternately, the atom from the same excited state can make a transition to the second excited state by successively emitting two photons of energies 4.25 eV and 5.95 eV respectively.
Determine the values of n and Z. **(IIT-JEE 1994)**
(Ionization energy of H-atom = 13.6 eV)

47. Hydrogen atom in its ground state is excited by means of monochromatic radiation of wavelength 975 Å. How many different lines are possible in the resulting spectrum? Calculate the longest wavelength amongst them. You may assume the ionization energy for hydrogen atom as 13.6 eV. **(IIT-JEE 1982)**

48. Ultraviolet light of wavelengths 800 Å and 700 Å when allowed to fall on hydrogen atoms in their ground state is found to liberate electrons with kinetic energy 1.8 eV and 4.0 eV respectively. Find the value of Planck's constant. **(IIT-JEE 1983)**

49. A doubly ionised lithium atom is hydrogen-like with atomic number 3.
(*a*) Find the wavelength of the radiation required to excite the electron in Li^{2+} from the first to the third Bohr orbit. (Ionisation energy of the hydrogen atom equals 13.6 eV.) **(IIT-JEE 1985)**
(*b*) How many spectral lines are observed in the emission spectrum of the above excited system?

Xray

Single Correct

50. Which one of the following statements is wrong in the context of X-rays generated from an X-ray tube? **(IIT-JEE 2008)**
(*a*) Wavelength of characteristic X-rays decreases when the atomic number of the target increases
(*b*) Cut-off wavelength of the continuous X-rays depends on the atomic number of the target
(*c*) Intensity of the characteristic X-rays depends on the electrical power given to the X-ray tube
(*d*) Cut-off wavelength of the continuous X-rays depends on the energy of the electrons in the X-ray tube

51. Electrons with energy 80 keV are incident on the tungsten target of an X-ray tube. K-shell electrons of tungsten have 72.5 keV energy. X-rays emitted by the tube contain only **(IIT-JEE 2000)**
(*a*) a continuous X-ray spectrum (Bremsstrahlung) with a minimum wavelength of ≈ 0.155 Å
(*b*) a continuous X-ray spectrum (Bremsstrahlung) with all wavelengths
(*c*) the characteristic X-ray spectrum of tungsten
(*d*) a continuous X-ray spectrum (Bremsstrahlung) with a minimum wavelength of ≈ 0.155Å and the characteristic X-ray spectrum of tungsten

52. The K_α X-ray emission line of tungsten occurs at $\lambda = 0.021$ nm. The energy difference between K and L levels in this atom is about **(IIT-JEE 1997)**
(*a*) 0.51 MeV (*b*) 1.2 MeV (*c*) 59 keV (*d*) 13.6 eV

53. X-rays are produced in an X-ray tube operating at a given accelerating voltage. The wavelength of the continuous X-rays has values from **(IIT-JEE 1998)**
(*a*) 0 to ∞
(*b*) λ_{min} to ∞ where $\lambda_{min} > 0$
(*c*) 0 to λ_{max} where $\lambda_{max} < \infty$
(*d*) λ_{min} to λ_{max} where $0 < \lambda_{min} < \lambda_{max} < \infty$

54. The shortest wavelength of X-rays emitted from an X-ray tube depends on **(IIT-JEE 1982)**
(*a*) the current in the tube
(*b*) the voltage applied to the tube
(*c*) the nature of the gas in tube
(*d*) the atomic number of the target material

55. The X-ray beam coming from an X-ray tube will be **(IIT-JEE 1985)**
(*a*) monochromatic
(*b*) having all wavelengths smaller than a certain maximum wavelength
(*c*) having all wavelengths larger than a certain minimum wavelength
(*d*) having all wavelengths lying between a minimum and a maximum wavelength

Multiple Correct

56. In an X-ray tube, electrons emitted from a filament (cathode) carrying current I hit a target (anode) at a distance d from the cathode. The target is kept at a potential V higher than the cathode resulting in emission of continuous and characteristic X-rays. If the filament current I is decreased to $\frac{I}{2}$, the potential difference V is increased to $2V$, and the separation distance d is reduced to $\frac{d}{2}$, then
C-16.61 W-17.98 UA-49.69 PC-15.72 (JEE Adv. 2020)
(*a*) The cut-off wavelength will reduce to half, and the wavelengths of the characteristic X-rays will remain the same
(*b*) The cut-off wavelength as well as the wavelengths of the characteristic X-rays will remain the same
(*c*) The cut-off wavelength will reduce to half, and the intensities of all the X-rays will decrease
(*d*) The cut-off wavelength will become two times larger, and the intensity of all the X-rays will decrease

57. The potential difference applied to an X-ray tube is increased. As a result, in the emitted radiation **(IIT-JEE 1988)**
(*a*) the intensity increases
(*b*) the minimum wavelength increases
(*c*) the intensity remains unchanged
(*d*) the minimum wavelength decreases

@PME_CBSE_X @RAJ_EDUNET

Fill in the Blanks

58. A potential difference of 20 kV is applied across an X-ray tube. The minimum wavelength of X-rays generated is ..... Å. **(IIT-JEE 1996)**

59. In an X-ray tube, electrons accelerated through a potential difference of 15, 000 V strike a copper target. The speed of the emitted X-ray inside the tube is ..... m/s. **(IIT-JEE 1992)**

60. To produce characteristic X-rays using a tungsten target in an X-ray generator, the accelerating voltage should be greater than ..... V and the energy of the characteristic radiation is ..... eV. (The binding energy of the innermost electron in tungsten is 40 keV). **(IIT-JEE 1983)**

61. When the number of electrons striking the anode of an X-ray tube is increased the ..... of the emitted X-rays increases, while when the speeds of the electrons striking the anode are increased the cut-off wavelength of the emitted X-rays ..... . **(IIT-JEE 1986)**

Subjective

62. X-rays are incident on a target metal atom having 30 neutrons. The ratio of atomic radius of the target atom and ^4_2He is $(14)^{1/3}$. **(IIT-JEE 2005)**

(*a*) Find the mass number of target atom.

(*b*) Find the frequency of k_α line emitted by this metal.

($R = 1.1 \times 10^7\ m^{-1}$, $c = 3 \times 10^8$ m/s)

63. Characteristic X-rays of frequency 4.2×10^{18} Hz are produced when transitions from *L*-shell to *K*-shell take place in a certain target material. Use Mosley's law to determine the atomic number of the target material. Given Rydberg's constant $R = 1.1 \times 10^7\ m^{-1}$. **(IIT-JEE 2003)**

@FAKE_CBSE X @RAJ_EDUNET

ANSWER KEY

EE-Main

1. (*b*)	2. [144.00]	3. (*c*)	4. (121)	5. (*c*)	6. [6]	7. (*b*)	8. (*a*)	9. (*d*)	10. [32]
11. (*c*)	12. (*d*)	13. (*a*)	14. [6588]	15. (*a*)	16. [16]	17. (*d*)	18. [122]	19. [156]	20. (*d*)
21. [136]	22. [828]	23. (*c*)	24. (*c*)	25. (*d*)	26. (*d*)	27. (*b*)	28. (*a*)	29. [2]	30. [425]
31. [3]	32. (*c*)	33. (*d*)	34. (*b*)	35. (*d*)	36. (*a*)	37. (*b*)	38. [3]	39. (*a*)	40. (*b*)
41. (*a*)	42. (*d*)	43. (*c*)	44. (*a*)	45. (*a*)	46. (*c*)	47. (*b,c*)	48. (*c*)	49. (*a*)	50. (*b*)
51. (*d*)	52. (*b*)	53. (*a*)	54. [3]	55. [4125]	56. [27]	57. [3668]	58. [5]	59. [27]	60. [27]
61. [114]	62. (*a*)	63. (*b*)	64. [5]	65. [5]	66. (*d*)	67. (*c*)	68. (*b*)	69. (*a*)	70. (*a*)
71. (*d*)	72. (*a*)	73. [15]	74. [15]	75. (a,d)	76. (*a*)	77. [486]	78. [10553.33]		79. (*c*)
80. (*a*)	81. (*b*)	82. (*c*)	83. (*a*)	84. (*d*)	85. (*b,c*)	86. (*c*)	87. [17]	88. [7]	89. (*b*)
90. [51]	91. (*b*)	92. (*d*)	93. (*b*)	94. [10]	95. (*a,c*)				

E-Advanced

1. (*a*)	2. (*d*)	3. (*c*)	4. (*d*)	5. (*b,c*)	6. (*a,b,d*)	7. (*a,c*)	8. (*a,c,d*)	9. (*d*)	10. (*b*)
11. (*c*)	12. (*a*)	13. (*b*)	14. (*d*)	15. (*c*)	16. (*c*)	17. (*a*)	18. [2]	27. (*b*)	28. (*b*)
29. (*a*)	30. (*b*)	31. (*d*)	32. (*a*)	33. (*b*)	34. (*d*)	35. (*c*)	36. (*c*)	37. (*a,d*)	38. (*b,c*)
39. [3]	40. [5]	41. [6]	50. (*b*)	51. (*d*)	52. (*c*)	53. (*b*)	54. (*b*)	55. (*c*)	56. (*a,c*)
57. (*c,d*)									

EXPLANATIONS

JEE-Main

1. (*b*) As radius is inversely proportional to Z

$$r \propto \frac{n^2}{Z} \Rightarrow \frac{r_4}{r_3} = \frac{4^2}{3^2} \Rightarrow r_4 = \frac{16}{9}R$$

2. [144.00]
Longest wavelength corresponds minimum energy
Hence transition takes place between $n = 3$ and $n = 4$

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = RZ^2\left(\frac{1}{9} - \frac{1}{16}\right)$$

$$= \frac{7RZ^2}{9\times16}$$

$$\Rightarrow \lambda = \frac{144}{7R} \text{ for } Z = 1 \quad \therefore \alpha = 144$$

3. (*c*) According to Rutherford atomic model, most of mass of atom and all its positive charge is concentrated in tiny nucleus & electron revolve around it.
An atom is a spherical cloud of positive charges with electrons embedded in it, this is Thomson's model.
Hence,
Statement I is true but statement II false.

4. (121) For minimum potential difference electron has to make transition from $n = 3$ to $n = 2$ state but first electron has to reach to $n = 3$ state from ground state. So, energy of bombarding electron should be equal to energy difference of $n = 3$ and $n = 1$ state.

$$\Delta E = 13.6\left[1 - \frac{1}{3^2}\right]e = eV$$

$$\frac{13.6\times8}{9} = V$$

$$V = 12.09 \text{ V} \approx 12.1 \text{ V}$$

So, $\alpha = 121$

5. (*c*) For each orbit (n) in a hydrogen atom, the ratio of kinetic energy to the absolute value of potential energy is consistently 1:2.

i.e, $\frac{1}{2}|PE| = KE$ for each value of n (orbit)

$$\therefore \frac{KE}{|PE|} = \frac{1}{2}$$

6. [6] We know that, $E_n = -\frac{13.6}{n^2} = -0.85$
$\Rightarrow n = 4$
No of transition

$$= \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$$

7. (*b*)

8. (*a*) According to Rayleigh equation,

$$\frac{1}{\lambda} = \frac{13.6z^2}{hc}\left[\frac{1}{1^2} - \frac{1}{2^2}\right] \quad ...(i)$$

$$\frac{1}{\lambda'} = \frac{13.6z^2}{hc}\left[\frac{1}{1^2} - \frac{1}{3^2}\right] \quad ...(ii)$$

Divide Equation (*i*) and (*ii*)

$$\lambda' = \frac{27}{32}\lambda$$

9. (*d*) Transition from n → 1 to n → 3
$\Delta E = 12.1$eV

10. [32] Energy released in transition,

$$E = -13.6z^2\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

$$\Rightarrow h\nu = C\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

$$\Rightarrow \frac{\nu_1}{\nu_2} = \frac{\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]_{2-1}}{\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]_{3-1}} = \frac{3}{4}\times\frac{9}{8}$$

$$\Rightarrow \frac{\nu_1}{\nu_2} = \frac{27}{32}$$

$$\Rightarrow \nu_2 = \frac{32}{27}\nu_1 = \frac{32}{27}\times3\times10^{15}\text{Hz}$$

$$= \frac{32}{9}\times10^{15}\text{Hz}$$

11. (*c*) $\vec{L} = \vec{r}\times m\vec{v}$

$$L = mvr = \frac{nh}{2\pi} = \frac{4h}{2\pi} = \frac{2h}{\pi}$$

12. (*d*) The centripetal fore on the electron,

$$F = \frac{k(Ze)(e)}{r^2} = \frac{mv^2}{r}$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}\frac{K(Ze)(e)}{r}$$

$$PE = -\frac{K(Ze)(e)}{r}$$

Total energy,

$$TE = \frac{K(Ze)(e)}{2r} - \frac{K(Ze)(e)}{r}$$

$$= \frac{-K(Ze)(e)}{2r}$$

$$TE = \frac{PE}{2}$$

$$2TE = PE$$

13. (*a*) The centripetal force on the electron,

$$F_c = \frac{mv^2}{r}$$

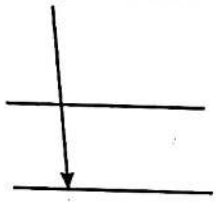
The electrostatic force is equal to the centripetal force, so $\frac{Kq_1q_2}{r^2} = \frac{mv^2}{r}$

$$mv^2r^2 = Kq_1q_2r$$

$$\frac{m^2v^2r^2}{m} = Kq_1q_2r$$

$$\frac{L^2}{m} = Kq_1q_2r \Rightarrow L \propto \sqrt{r}$$

14. [6588]
Lyman Series



Shortest, $\frac{hc}{\lambda} = 13.6\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$$\therefore \frac{hc}{\lambda_0} = 13.6(1)$$

Smaller wavelength corresponds to higher energy & vice versa
Balmer Series :
$n_2 = 3$ and $n_1 = 2$

$$\frac{hc}{\lambda_1} = 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\Rightarrow \frac{hc}{\lambda_1} = 13.6\times\left(\frac{5}{36}\right)$$

$$\Rightarrow \frac{13.6\lambda_0}{\lambda_1} = 13.6\times\frac{5}{36}$$

$$\lambda_1 = \frac{\lambda_0\times36}{5} = \frac{915\times36}{5} = 6588$$

15. (*a*) Rydberg formula

$$\frac{1}{\lambda} = Rz^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow \frac{1}{\lambda} \propto \left(\frac{1}{n_1^2} - \frac{1}{n}\right.$$

@FAKE_CBSE_X @RAJ EDUNET

Shortest wavelength ⇒ Maximum energy
For Balmen $n_1 = 2, n_2 = \infty$
For Lymen $n_1 = 1, n_2 = \infty$

$$\frac{\frac{1}{\lambda_L}}{\frac{1}{\lambda_B}} = \frac{\left(\frac{1}{1^2}\right)}{\left(\frac{1}{2^2}\right)} = 4:1$$

16. *[16]* Given, $r = 8.48 = A^\circ$
Since,

$$r = 0.529\frac{n^2}{Z}$$

$$\therefore 8.48 = 0.529\, n^2 \frac{n^2}{1}$$

$n^2 = 16 \Rightarrow n = 4$
Energy of $\bar{e}$.

$$E \propto \frac{1}{n^2}$$

$$\therefore E_{n^{th}} = \frac{E}{16}$$

$x = 16$

17. *(d)* For longest wavelength in Paschen's series;
$n_1 = 3, n_2 = 4$
From Rydberg Gormula

$$\frac{1}{\lambda} = R\left[\frac{1}{(3)^2} - \frac{1}{(4)^2}\right]$$

$$\frac{1}{\lambda} = R\left[\frac{1}{9} - \frac{1}{16}\right] = \frac{16\times 9}{7\times 1.097\times 10^7}$$

$\lambda = 1.876 \times 10^{-6}$m

18. *[122]* $\frac{hc}{\lambda} = 10.2eV$

$$\lambda = \frac{1245eV - \text{nm}}{10.2eV} = 122.06\text{nm}$$

19. *[156]*
The maximum velocity of the α-particle,

$$v = \sqrt{\frac{4KZe^2}{mr_{\min}}}$$

$$= \sqrt{\frac{4\times 9\times 10^9 \times 80}{6.72\times 10^{-27}\times 4.5\times 10^{-14}}} \times 1.6\times 10^{-19}$$

$$V = 9.759\times 10^{25}\times 1.6\times 10^{-19}$$

$$= 156\times 10^5 \text{ m/s}$$

20. *(d)* Hydrogen will be excited to first excited state therefore it will emit one spectral line corresponding to transition *from* energy level 2 to 1

21. *[136]*

$$E_B = 13.6\frac{Z^2}{n^2}$$

For Li^{2+},
$Z = 3, n = 3$

$$E_{Li^{2+}} = 13.6\left(\frac{3^2}{3^2}\right) = 13.6eV$$

Comparing above result with $x \times 10^{-1}$eV we get
$x = 136$

22. **[828]** Ground state energy = −13.6 eV

$$\therefore \frac{-13.6\text{eV}}{n^2} = -13.6 + 12.75$$

$$\Rightarrow \frac{-13.6\text{eV}}{n^2} = -0.85$$

$$\Rightarrow \boxed{n = 4}$$

$$\text{Angular momentum} = \frac{nh}{2\pi} = \frac{4h}{2\pi} = \frac{2h}{\pi}$$

⇒ Angular momentum

$$= \frac{2}{\pi}\times 4.14\times 10^{-15}$$

$$= \frac{828\times 10^{-17}}{\pi}\text{eVs}$$

23. (c) Energy used to Bombard gaseous hydrogen,
$E = 12.5\ eV$
Energy of excited state = The energy of gaseous hydrogen after bombardment E_n
$= -13.6\ eV + 12.5\ eV = -1.1\ eV$
∴ orbital no of excited state,

$$n = \sqrt{\frac{-13.6eV}{E_n}} = \sqrt{\frac{-13.6}{-1.1}} = 3.5 \approx 3$$

So, number of spectral lines is

$$\frac{3(3-1)}{2} = 3$$

24. *(c)* Angular momentum, $L = \frac{nh}{2\pi}$

For Bohr orbit is, $L_1 = L = \frac{1.h}{2\pi}$

In second orbit of hydrogen atom $(n = 2)$,

$$L_2 = \frac{2h}{2\pi} = 2L$$

So, change momentum $= L_2 - L_1 = 2L - L = L$

25. *(d)* $\lambda = \frac{hc}{\Delta E}$

$\Delta E_A = 2.2\text{eV} = 2.2 \times 1.6 \times 10^{-19}J$
$\Delta E_B = 5.2\text{eV} = 5.2 \times 1.6 \times 10^{-19}J$
$\Delta E_C = 3\text{eV} = 3 \times 1.6 \times 10^{-19}J$
$\Delta E_D = 10\text{eV} = 10 \times 1.6 \times 10^{-19}J$

$$\lambda_A = \frac{6.62\times 10^{-34}\times 3\times 10^8}{2.2\times 1.6\times 10^{-19}} = 564\ nm$$

$$\lambda_B = \frac{1241}{5.2}\text{nm} = 238.65\text{nm}$$

$$\lambda_C = \frac{1241}{3}\text{nm} = 413.66\text{nm}$$

$$\lambda_D = \frac{1241}{10} = 124.1\text{nm}$$

26. *(d)* $\because E_n = -\frac{13.6Z^2}{n^2}eV$

$$\Rightarrow \Delta E = 13.6Z^2\left[\frac{1}{2^2} - \frac{1}{4^2}\right]eV$$

$$= 13.6\times (4)^2\left(\frac{1}{4} - \frac{1}{16}\right)eV$$

$$\Rightarrow \Delta E = 40.8eV$$

27. *(b)* We know that, Radius of n^{th} orbit,

$$R = 0.529\frac{n^2}{z}\text{Å}, \frac{R_3}{R_2} = \frac{9}{4}, R_3 = \frac{9}{4}R_2$$

$$\therefore R_3 = 2.25\ R$$

28. (a) $U = \frac{1}{2}m\omega^2 r^2$

$$F = -\frac{du}{dr} = -m\omega^2 r = \frac{mv^2}{r} \Rightarrow v = \omega r$$

$$\because mvr = \frac{nh}{2\pi}$$

$$\therefore m\omega r^2 = \frac{nh}{2\pi} \Rightarrow r = \sqrt{\frac{nh}{2\pi m\omega}} \Rightarrow r \propto \sqrt{n}$$

29. [2] $r \propto \frac{n^2}{z} \Rightarrow \frac{r_{He^+}}{r_{Be^{3+}}} = \left(\frac{\eta_{He^+}}{\eta_{Be^{3+}}}\right)^2 \times \frac{z_{Be^{3+}}}{z_{He^+}}$

$$\frac{r_{He^+}}{r_{Be^{3+}}} = \left(\frac{2}{4}\right)^2 \times \left(\frac{4}{2}\right) = \frac{1}{2}$$

30. [425]

$$r_n = r_0\frac{n^2}{z} \Rightarrow r_n = 0.51\times\frac{(5)^2}{3}\text{Å}$$

$$= 4.25\times 10^{-10}\ N$$

$$= 425 \times 10^{-12}\ m$$

31. [3] We know that, $d \propto \cot^2\frac{\theta}{2}$

$$\Rightarrow \sqrt{d} \propto \cot\frac{\theta}{2}$$

$$\frac{\sqrt{d_1}}{\sqrt{d_2}} = \frac{\cot\frac{\theta_1}{2}}{\cot\frac{\theta_2}{2}} \Rightarrow \sqrt{x}$$

$$= \frac{\cot 30^\circ}{\cot 45^\circ} \Rightarrow \sqrt{x} = \sqrt{3} \Rightarrow x = 3$$

32. (c) According to Rutherford, e– revolves around nucleus in circular orbit. Thus e^- is always accelerating (centripetal acceleration). An accelerating change emits *EM* radiation and thus e^- should loose energy and fall into heavy nucleus collapsing the whole atom.

33. *(d)* As we know the atomic number
$He^+, Z_{He^+} = 2$
and the atomic number Hydrogen
$H^+, Z_{H^+} = 1$

Since, $v \propto \frac{Z}{n} \propto Z$ $(n = \text{constant})$

@EAKE_CBSE_X @RAJEDUNET

We have;

$v_{He^+} \propto Z_{He^+}$

and, $v_{H^+} \propto Z_{H^+}$ ...(i)

Now, On dividing equation (i) and equation (ii) we have; ...(ii)

$$\frac{v_{He^+}}{v_H^+} = \frac{Z_{He^+}}{Z_H^+} \Rightarrow \frac{v_{He^+}}{v_H^+} = \frac{2}{1}$$

34. (*b*) Given $\Delta E = 10.2$ eV

For atom in ground state, $n_1 = 1$.

$$\therefore \Delta E = 13.6\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$2 = 13.6\left(\frac{1}{1^2} - \frac{1}{n_2^2}\right)$$

$$\frac{10.2}{13.6} = 1 - \frac{1}{n_2^2}$$

$n_2 = 2$

Increase in Angular Momentum, $\Delta L = L_f - L_i$

$$= \frac{n_2 h}{2\pi} - \frac{n_1 h}{2\pi} = \frac{2h}{2\pi} - \frac{h}{2\pi}$$

$$= \frac{h}{2\pi}$$

$$\Delta L = \frac{6.6\times10^{-34}}{2\times3.14} = 1.05\times10^{-34}\ J-\text{sec}$$

35. (*d*) When $\bar{e}$ jump from lower to higher energy level it absorbed energy.

Therefore statement I is wrong

For statement II

For the jumping of electron from higher energy orbit

(E_2) to lower energy orbit (E_1)

$h\nu = E_2 - E_1$

$$\nu = \frac{E_2 - E_1}{h}$$

36. (*a*) $mvr = \frac{nh}{2\pi}$

Therefore, momentum, $p = mv = \frac{nh}{2\pi r}$

37. (*b*) Potential energy: An electron possesses some potential energy because it is found in the field of nucleus potential energy of an electron in n th orbit of radius r_n is given by

$$U = \frac{kZe^2}{r_n}$$

Where Z = atomic number, n = orbit number and

r_n = radius of the nth orbit

Kinetic energy: Electron possesses kinetic energy because of its motion. Closer orbits have greater kinetic energy than outer ones.

$$K = \frac{kZe^2}{2r_n} = -\frac{U}{2} = \frac{kZe^2}{2r_n}$$

Total energy: Total energy (TE) is the sum of potential energy and kinetic energy i.e. $E = K + U$

$$TE = -13.6\frac{Z^2}{n^2}\text{eV}$$

The relationship between PE/TE, and KE is given by:

$KE = -TE = -PE/2$

From above it is clear that as n increases, the potential energy increases, kinetic energy decreases and total energy increases.

38. [3] $\frac{mv^2}{r}\left|\frac{dU}{dr}\right| = 4|U_0|r^3$ ... (*i*)

$mvr \Rightarrow \frac{nh}{2\pi}$ ... (*ii*)

From (*i*) and (*ii*)

$$r = \left(\frac{nh}{4\pi\sqrt{|U_0|}}\right)^{\frac{1}{3}} \Rightarrow r \propto n^{\frac{1}{3}}$$

39. (*a*) $v_n \propto \frac{1}{n}$

40. (*b*) $E \propto \frac{1}{r}, r \propto \frac{1}{m}$ $E \propto m$

Ionization potential = $13.6 \times \frac{(m_\mu)\text{ eV}}{(m_e)}$

$= 13.6 \times 207\text{ eV} = 2815.2\text{ eV}$

41. (*a*) Ground state energy of the (H–atom)

$E_{ground} = -13.6\ eV$

$E_{Carbon} = E_{Ground}$ of H_{atom}

$$\Rightarrow 13.6\times\frac{6^2}{n^2} = -13.6eV \Rightarrow n = 6$$

42. (*d*) Minimum required energy,

$$E_{min} = \frac{hc}{\lambda_{max}}$$

$$E_{min} = \frac{1242eV - nm}{621nm} = 2eV$$

43. (*c*) $E = -E_0 \times \frac{1}{n^2}$

$$\Rightarrow \Delta E = -E_0 \times \frac{2}{n^3} \times (\Delta n)$$

$$\Rightarrow h\nu = 2E_0 \times 1 \times \frac{1}{n^3}, \Rightarrow \nu \propto \frac{1}{n^3}$$

44. (*a*) $k = qV$

$$\frac{1}{2}mv^2 = qV$$

$$\Rightarrow v = \sqrt{\frac{2qV}{m}}, \frac{V_H}{V_{He}} = \sqrt{\frac{q_H m_{He}}{m_H q_{He}}} = 2:1$$

45. (a) Results of Rutherford gold foil experiment gives

$$N \propto \frac{1}{\sin^4\left(\frac{\theta}{2}\right)}$$

46. (*c*) $T \propto \frac{r}{v} \propto \frac{n^2}{z} \times \frac{n}{z} \propto \frac{n^3}{z^2} = \frac{n_1^3}{n_2^3} = \frac{1}{8}$

$T_2 = 8T_1 = 8 \times 1.6 \times 10^{-16} = 12.8 \times 10^{-16}$

$$f_2 = \frac{1}{12.8\times10^{-6}} \approx 7.8\times10^{14}$$

47. (*b,c*) $U = Fr$

[Using U = Potential energy and v = velocity, to avoid confusion between their symbols]

$$\Rightarrow \text{Force} = \frac{-dU}{dr} = -F$$

$\Rightarrow$ Magnitude of force = Constant = F

$$\Rightarrow F = \frac{mv^2}{R} \quad ...(i)$$

$$\Rightarrow mvR = \frac{nh}{2\pi} \quad ...(ii)$$

$$\Rightarrow F = \frac{m}{R} \times \frac{n^2h^2}{4\pi^2} \times \frac{1}{m^2R^2}$$

$$R = \left(\frac{n^2h^2}{4\pi^2mF}\right)^{1/3} \quad ...(iii)$$

$$\Rightarrow v = \frac{nh}{2\pi mR} \Rightarrow v = \frac{nh}{2\pi m}\left(\frac{4\pi^2mF}{n^2h^2}\right)^{1/3}$$

$$\Rightarrow v = \frac{n^{1/3}h^{1/3}F^{1/3}}{2^{1/3}\pi^{1/3}m^{2/3}} \quad ...(iv)$$

(*b*) is correct.

$$\Rightarrow E = \frac{1}{2}mv^2 + U = \frac{1}{2}mv^2 + FR$$

$$\Rightarrow E = \frac{1}{2}m\left(\frac{n^{2/3}h^{2/3}F^{2/3}}{2^{2/3}\pi^{2/3}m^{4/3}}\right) + F\times\left(\frac{n^2h^2}{4\pi^2mF}\right)^{1/3}$$

$$\Rightarrow E = \left(\frac{n^2h^2F^2}{4\pi^2m}\right)^{1/3}\left[\frac{1}{2}+1\right] = \frac{3}{2}\left(\frac{n^2h^2F^2}{4\pi^2m}\right)^{1/3}$$

48. (*c*) Energy supplied

$$E = \frac{12500}{980} = 12.75\text{eV}$$

$\therefore E_n - E_1 = 12.75$

$$\Rightarrow (13.6)\left(1 - \frac{1}{n^2}\right) = 12.75$$

$\Rightarrow n^2 \approx 14.3 \Rightarrow n \approx 4$

New radius = $16a_0$

@FAKE_CBSE_X @RAJ_EDUNET

49. (a) $U = \frac{1}{2}kr^2$

Force, $F = -\frac{dU}{dr} = -kr$

For circular motion $\frac{mv^2}{r} = kr$ ...(i)

And $mvr = \frac{nh}{2\pi}$ ...(ii)

$\Rightarrow r^2 = \frac{nh}{2\pi\sqrt{km}} \Rightarrow r \propto \sqrt{n}$

Total energy,

$E = k + U$

$= \frac{1}{2}mv^2 + \frac{1}{2}kr^2$

$= \frac{1}{2}kr^2 + \frac{1}{2}kr^2$

[From quation (i)]

$E = kr^2 \Rightarrow E \propto n$

50. (b) Energy levels in Hydrogen like atom is given by

$E = -13.6\frac{z^2}{n^2}\text{eV}$

As He^+ is 1st excited state

$\therefore z = 2, n = 2$

$E = -13.6$ eV

As total energy of He^+ in 1st excited state is -13.6 eV, ionization energy should be $+13.6$ eV.

51. (d) $V_n \propto \frac{Z}{n}$

$Z = 1, \therefore V_n \propto \frac{1}{n}$

$\therefore \frac{V_3}{V_7} = \frac{7}{3}$

$\therefore V_3 = \frac{7}{3}V_7 \quad = \frac{7}{3} \times 3.6 \times 10^6 \, m/s$

$= 8.4 \times 10^6 \, m/s$

52. (b) $\lambda_{min} = \frac{hc}{\Delta E_{max}}$

For shortest wavelength, energy gap should be maximum.

So, correct choice is transition from $n = 3$ to $n = 1$.

53. (a) For a hydrogen atom, $E = \frac{-13.6eV}{n^2}$

$\Rightarrow \frac{hc}{\lambda} = \left[1 - \frac{1}{16}\right](13.6eV)$

$\Rightarrow, \lambda = 94.1 \, nm$

4. [3] Let the number of spectral time be n

$\therefore \frac{n(n-1)}{2} = 6$

$n^2 - n - 12 = 0$

$n^2 - 4n + 3n - 12 = 0$

$n(n-4) + 3(n-4)$

$n = 4, n = -3$ (ignore)

$\therefore h\nu = E_4 - E_1$

$\therefore \nu = 13.6\left(\frac{1}{1^2} - \frac{1}{4^2}\right) \times \frac{1}{4.25 \times 10^{-15}}$

$= 3 \times 1015$ Hz

55. [4125] $= hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$

$= 6.6 \times 10^{-34} \times 3 \times 10^8$

$\left(\frac{1}{500 \times 10^{-9}} - \frac{1}{600 \times 10^{-9}}\right)$

$= 6.6 \times 10^{-20}$ J

$= \frac{6.6 \times 10^{-20}}{1.6 \times 10^{-19}} eV = 4.125 \times 10^{-1} eV$

$= 4125 \times 10^{-4} \, eV$

56. [27]

For hydrogen atom $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

For balmer series, $n_1 = 2$

And for H_α, $n_2 = 3$, H_β, $n_2 = 4$

$\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{n_2^2}\right]$

$\frac{1}{\lambda_\alpha} = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}, \quad \lambda_\alpha = \frac{36}{5R}$

$\frac{1}{\lambda_\beta} = R\left[\frac{1}{4} - \frac{1}{16}\right] = \frac{3R}{16} \Rightarrow \lambda_\beta = \frac{16}{3R}$

$\frac{\lambda_\alpha}{\lambda_\beta} = \frac{36}{5R} \times \frac{3R}{16}, \quad \frac{\lambda_\alpha}{\lambda_\beta} = \frac{27}{20} = \frac{x}{20}$

$x = 27$

57. [3668] For Lyman series

$\frac{1}{\lambda_{(\text{Lowest})_L}} = RZ^2\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] = RZ^2$

For Balmer series

$\frac{1}{\lambda_{(\text{Lowest})}} = RZ^2\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] = \frac{RZ^2}{4}$

$\lambda_{(\text{Lowest})_B} = \frac{4}{RZ^2} = 4\lambda_{(\text{Lowest})_L} = 4 \times 917$

$= 3668$ Å

58. [5] As $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

For A to B, $n_1 = 2, n_2 = 3$

$\frac{1}{\lambda_1} = R(1)^2\left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right] = R\left(\frac{5}{36}\right)$ ... (i)

For B to C, $n_1 = 3, n_2 = 4$

$\& \frac{1}{\lambda_2} = R(1)^2\left[\frac{1}{(3)^2} - \frac{1}{(4)^2}\right]$

$= R\left(\frac{7}{144}\right)$ ... (ii)

Dividing (ii) by (i)

$\frac{\lambda_1}{\lambda_2} = \frac{7/144}{5/36} = \frac{7}{20} = \frac{7}{4 \times 5}$

$\therefore n = 5$

59. [27]

Electron jumps from second excited state → first excited state

$\Rightarrow \frac{hc}{\lambda_0} = 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$ ...(i)

For the electron to move from third excited state → second orbit

$n = 4 \rightarrow n = 2$

$\Rightarrow \frac{hc}{(20\lambda_0 / x)} = 13.6\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$ ...(ii)

Dividing equ (ii) by (i)

$\frac{x}{20} = \frac{\frac{1}{2^2} - \frac{1}{4^2}}{\frac{1}{2^2} - \frac{1}{3^2}}$

$\Rightarrow x = 27$

60. [27]

$\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$\Rightarrow \frac{1}{\lambda_1} = RZ^2\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = \frac{8}{9}RZ^2$ ...(i)

and, $\frac{1}{\lambda_2} = RZ^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3}{4}RZ^2$ ...(ii)

Dividing eqn (ii) by (i)

$\frac{\lambda_1}{\lambda_2} = \frac{27}{32} \Rightarrow x = 27$

61. [114]

$Z = 3$

$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right), n_1 = 1, n_2 = 3$

$\lambda = \frac{1}{8R} = 114 \times 10^{-10}$ m

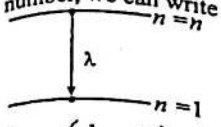
62. (a) $\Delta E_1 = -\frac{E_0}{4} + \frac{E_0}{1} = \frac{3}{4}E_0$

$\Delta E_2 = 0 - (-E_0) = E_0$

$\frac{\Delta E_1}{\Delta E_2} = \frac{3}{4}$

@FAKE_CBSE_X@RAJ_EDUNET

63. (*b*) According to definition of wave number, we can write

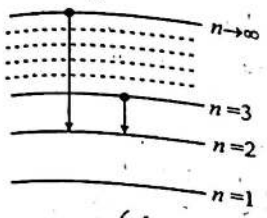


$$\frac{1}{\lambda}=R\left(\frac{1}{1^2}-\frac{1}{n^2}\right),\ \Rightarrow 1-\frac{1}{n^2}=\frac{1}{\lambda R}$$

$$\Rightarrow \frac{1}{n^2}=1-\frac{1}{\lambda R}=\frac{\lambda R-1}{\lambda R}\Rightarrow n=\sqrt{\frac{\lambda R}{\lambda R-1}}$$

64. [5] Formula of atomic energy of n^{th} level,

$$E_n=\frac{-13.6z^2}{n^2}$$



$$\Delta E_1=13.6\left(\frac{1}{2^2}-\frac{1}{3^2}\right)=\frac{5\times 13.6}{36}\text{ and}$$

$$\Delta E_2=13.6\left(\frac{1}{2^2}-\frac{1}{\infty^2}\right)$$

$$\frac{\Delta E_1}{\Delta E_2}=\frac{5}{9},\ \frac{x}{x+4}=\frac{5}{5+4},\ x=5$$

65. [5] For first line of Lyman series, $n_1=1$, $n_2=2$

$$\frac{1}{\lambda}=R\left(1-\frac{1}{4}\right)=\frac{3}{4}R,\ \lambda=\frac{4}{3R}$$

For 3rd line of Paschen series, $n_1=3, n_2=6$

$$\frac{1}{\lambda_3}=R\left(\frac{1}{3^2}-\frac{1}{6^2}\right)=\frac{R}{9}\times\frac{3}{4}$$

For 2nd line of Balmer series, $n_1=2, n_2=4$

$$\frac{1}{\lambda_2}=R\left(\frac{1}{2^2}-\frac{1}{4^2}\right)=\frac{R}{4}\times\frac{3}{4}$$

Thus, $a\lambda=\lambda_3-\lambda_2=\frac{12}{R}-\frac{16}{3R}=\frac{20}{3R}$

$$a\left(\frac{4}{3R}\right)=\frac{20}{3R}\Rightarrow a=5$$

66. (*d*) *A: For transition A, $n_1=1, n_2=\infty\Rightarrow$ Series limit of Lyman series*

B: For transition B, $n_1=2, n_2=5\Rightarrow$ Third line of Balmer series

C: For transition C, $n_1=3, n_2=5\Rightarrow$ Second line of Paschen series

67. (*c*) We know that, $\Delta E\propto\left(\frac{1}{n_2^2}-\frac{1}{n_1^2}\right)$

If $n_1=3$ and $n_2=2$

$$\left(\frac{1}{2^2}-\frac{1}{3^2}\right)=\frac{9-4}{36}=\frac{5}{36}$$

If $n_1=4$ and $n_2=3$

$$\left(\frac{1}{3^2}-\frac{1}{4^2}\right)=\frac{16-9}{144}=\frac{7}{144}$$

If $n_1=2$ and $n_2=1$

$$\left(\frac{1}{1^2}-\frac{1}{2^2}\right)=\frac{4-1}{4}=\frac{3}{4}$$

If $n_1=5$ and $n_2=4$

$$\left(\frac{1}{4^2}-\frac{1}{5^2}\right)=\frac{25-16}{400}=\frac{9}{400}$$

Since, $\Delta E=h\nu$.

Hence option (*c*) is the correct answer.

68. (*b*) Balmer series lies in the visible region.

69. (*a*) $h\nu_1=R\left(\frac{1}{1^2}-\frac{1}{3^2}\right)=\frac{8R}{9}$

$$h\nu_2=R\left(\frac{1}{1^2}-\frac{1}{2^2}\right)=\frac{3R}{4}$$

$$\frac{\nu_1}{\nu_2}=\frac{8/9}{3/4}=\frac{32}{27},\ \nu_2=\nu_1\times\left(\frac{27}{32}\right)$$

$$=\left(2.92\times10^{15}\right)\times\left(\frac{27}{32}\right)$$

$$=2.46\times10^{15}\text{ Hz}$$

70. (*a*) $\frac{1}{\lambda}=R\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

$$\therefore\frac{1}{\lambda}=109677.6cm^{-1}\times\left[\frac{1}{1}-\frac{1}{2^2}\right]$$

$$\Rightarrow\lambda=\frac{1}{82258.2}\text{cm}=121.8\text{nm}$$

71. (*d*) The wavelength of spectral line of the third member of Lyman series;

$$\frac{1}{\lambda_1}=RZ^2\left(\frac{1}{1^2}-\frac{1}{4^2}\right)$$

The wavelength of spectral line of the first member of paschen series;

$$\frac{1}{\lambda_2}=RZ^2\left(\frac{1}{3^2}-\frac{1}{4^2}\right)$$

$$\frac{1/\lambda_1}{1/\lambda_2}=\frac{1-\frac{1}{16}}{\frac{1}{9}-\frac{1}{16}}\Rightarrow\frac{\lambda_2}{\lambda_1}=\frac{\frac{15}{16}}{\frac{7}{9\times16}}$$

$$=\frac{15\times9}{7}\Rightarrow\frac{\lambda_1}{\lambda_2}=\frac{7}{135}$$

72. (*a*) As $n=5$ to $n=1$

$\therefore\Delta E=13.6-0.54$

$\Delta E=13.06\,eV$ ... (i)

Using conservation of linear momentum

$$\frac{h}{\lambda}=m_Hv_H\Rightarrow\frac{hc}{\lambda}=cm_Hv_H\Rightarrow v_H=\frac{\frac{hc}{\lambda}}{cm_H}$$

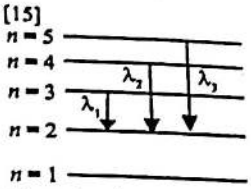
$$=\frac{\Delta E}{cm_H}=\frac{13.06\times1.6\times10^{-19}}{3\times10^8\times1.67\times10^{-27}}=4.17m/s$$

73. [15]

No. of different wavelengths

$$=\frac{n\times(n-1)}{2}=\frac{6\times5}{2}=15$$

74. [15]



The ratio of wavelength of first and third spectral lines

$$\frac{\lambda_1}{\lambda_3}=\frac{R\left(\frac{1}{2^2}-\frac{1}{5^2}\right)}{R\left(\frac{1}{2^2}-\frac{1}{3^2}\right)}=\frac{21}{100}\times\frac{36}{5}$$

$$=1.512\approx15\times10^{-1}$$

75. (*a,d*) For hydrogen atom, $z=1$

$$\frac{1}{\lambda}=R\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right),$$

where $R=1.0973\times107\text{ m}^{-1}=$ Rydberg constant.

For the Lyman series, $n_1=1$ and $n_2=2$, 3, 4,

$$\frac{1}{\lambda}=R\left(1-\frac{1}{n_2^2}\right)$$

$\lambda=\lambda_{max}$, when $n_2=2$

$$\frac{1}{\lambda_{max}}=\frac{3R}{4}\Rightarrow\lambda_{max}=\frac{4}{3R}=121.5\text{nm}$$

$$\lambda=\left(\frac{n_2^2}{n_2^2-1}\right)\frac{1}{R}=\left[1+\frac{1}{\left(n_2^2-1\right)}\right]\lambda_0$$

$$=\left(1+\frac{1}{m^2}\right)\lambda_0$$

$$\lambda=\left(1+\frac{1}{\text{m}^2}\right)\lambda_0$$

where,

$m^2=\left(n_2^2-1\right)=$ an integer

$m=\sqrt{n_2^2-1}=$ not an integer

For the Balmer series, $n_1=2$ and $n_2=3$, 4, 5, 6, ... ∞ $\frac{1}{\lambda}=R\left(\frac{1}{4}-\frac{1}{n_2^2}\right)$

$\lambda=\lambda_{max}$, when $n_2=3$

$$\frac{1}{\lambda_{max}}=\frac{5R}{36},\ \lambda_{max}=\frac{36}{5R}=656.2\text{nm}$$

$\lambda=\lambda_{min}$, when $n_2=\infty$

$$\Rightarrow\lambda_{min}=\frac{4}{R}=364.5\text{nm}$$

Hence, for the Balmer series,

@FAKE_CBSE_K @RAJ_EDUNET

$$\frac{\lambda_{max}}{\lambda_{min}} = \frac{36/5R}{4/R} = \frac{9}{5}$$

For the Paschen series, $n_1 = 3$ and $n_2 = 4, 5, 6, \ldots \infty$

$$\frac{1}{\lambda} = R\left(\frac{1}{9} - \frac{1}{n_2^2}\right)$$

$\lambda = \lambda_{max}$, when $n_2 = 4$

$$\frac{1}{\lambda_{max}} = R\left(\frac{1}{9} - \frac{1}{16}\right) = \frac{7R}{144}$$

$$\Rightarrow \lambda_{max} = \frac{144}{7R} = 1874.7\,\text{nm}$$

$\lambda = \lambda_{min}$, when $n_2 = \infty$

$$\frac{1}{\lambda_{min}} = \frac{R}{9} \Rightarrow \lambda_{min} = \frac{9}{R} = 820.2\ \text{nm}$$

76. (*a*) $\frac{hc}{\lambda} = (13.6\,\text{eV})z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$$\frac{hc}{\lambda} = (13.6\,\text{eV})(3^2)\left[\frac{1}{1^2} - \frac{1}{3^2}\right]$$

$$\Rightarrow \frac{hc}{\lambda} = (13.6eV)(9)\left(\frac{8}{9}\right)$$

Wavelength $= \frac{1240}{8\times13.6}\text{nm} = 11.39\ \text{nm}$

77. [486]

We have, $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For first member of Balmer series, $n_1 = 2, n_2 = 3$

$$\frac{1}{\lambda_1} = R(1)^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5R}{36}$$

For second member of Balmer series, $n_1 = 2, n_2 = 4$

$$\frac{1}{\lambda_2} = R(1)^2\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3R}{16}.$$

$$\frac{\lambda_2}{\lambda_1} = \frac{20}{27},\ \lambda_2 = \frac{20}{27}\times6561\ \text{Å} = 4860\ \text{Å}$$

Hence, wavelength of the second member of the Balmer series is 486 nm.

78. [10553.33] From, Bohr's atom model for hydrogen atom,

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\frac{1}{\lambda_{min}} = R\left[\frac{1}{1} - \frac{1}{\infty}\right] = R$$

$$[n = \infty \to n = 1]$$

$$\frac{1}{\lambda_{max}} = R\left[\frac{1}{1} - \frac{1}{4}\right] = \frac{3R}{4}$$

$$[n = 2 \to n = 1]$$

$$\Rightarrow \Delta\lambda = \frac{4}{3R} - \frac{1}{R} = \frac{1}{3R} = 304 \quad \ldots(i)$$

For Paschan

$$\frac{1}{\lambda_{min}} = R\left[\frac{1}{9}\right] \quad [n = \infty \to h = 3]$$

$$\Rightarrow \frac{1}{\lambda_{max}} = R\left[\frac{1}{9} - \frac{1}{16}\right] = \frac{7R}{144}$$

$$\Rightarrow \Delta\lambda = \frac{81}{7R} \Rightarrow \Delta\lambda = \frac{81\times3}{7}\times304$$

$$= 10553.14\text{Å}$$

79. (*c*) $E = E_1 + E_2$

$$13.6(2)^2\left(\frac{1}{1^2} - \frac{1}{n^2}\right) = \frac{1240}{108.5} + \frac{1240}{30.4}$$

$$\left(1 - \frac{1}{n^2}\right) = \frac{52.22}{54.4}$$

$$\frac{1}{n^2} = \frac{2.18}{54.4} \Rightarrow n^2 = 25 \Rightarrow n = 5$$

80. (*a*) $\frac{hc}{\lambda} = 13.6eV(9)\left\{1 - \frac{1}{16}\right\}$

$$\frac{1240eV}{\lambda} = \frac{15}{16}\times9\times13.6eV$$

$\Rightarrow \lambda = 10.8$ nm

Hence, option (a) is correct answer.

81. (*b*) Energy released for transition (n = 2 to n = 1)

$$E = 13.6Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$Z = 1, n_1 = 1, n_2 = 2$

$$E_H = 13.6\times1\times\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$= 13.6\times\frac{3}{4}\times\text{eV}$$

For He^+ ions $Z = 2$

Using option

(*a*) $n = 1$ to $n = 4$

$$E = 13.6\times2^2\times\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = 13.6\times\frac{15}{4}\text{eV}$$

(*b*) $n = 2$ to $n = 4$

$$E = 13.6\times2^2\times\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = 13.6\times\frac{3}{4}\text{eV}$$

(*c*) $n = 2$ to $n = 5$

$$E = 13.6\times2^2\times\left(\frac{1}{2^2} - \frac{1}{5^2}\right) = 13.6\times\frac{21}{25}\text{eV}$$

(*d*) $n = 2$ to $n = 3$

$$E = 13.6\times2^2\times\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 13.6\times\frac{5}{9}\text{eV}$$

Hence the possible transition is $n = 2 \to n = 4$

82. (*c*) $\frac{1}{660} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5R}{36}$ ...(i)

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3R}{16} \quad \ldots(ii)$$

Equation (i) + (ii)

$$\frac{\lambda}{660} = \frac{5\times16}{36\times3} \Rightarrow \lambda$$

$$= \frac{660\times5\times16}{36\times3} = 488.9nm$$

83. (*a*) We know that, $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$;

$$\frac{1}{\lambda_1} = R\left(\frac{1}{3^2} - \frac{1}{4^2}\right) \Rightarrow \frac{1}{\lambda_1} = R\left(\frac{7}{9\times16}\right);$$

$$\frac{1}{\lambda_2} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) \Rightarrow \frac{1}{\lambda_2} = R\left(\frac{5}{4\times9}\right)$$

$$\frac{\lambda_1}{\lambda_2} = \frac{\frac{5}{36}}{\frac{7}{9\times16}} = \frac{5\times9\times16}{7\times36} = \frac{20}{7}$$

84. (*d*) For $M \to L$ steel

$$\frac{1}{\lambda} = K\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{K\times5}{36}$$

for $N \to L$

$$\frac{1}{\lambda'} = K\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{K\times3}{16}\ \lambda' = \frac{20}{27}\lambda$$

85. (*b,c*)

$$\frac{hc}{\lambda_\alpha} = 13.6\left[\frac{1}{1} - \frac{1}{4^2}\right] \quad \ldots(i)$$

$$\frac{hc}{\lambda_e} = 13.6\left[\frac{1}{m^2} - \frac{1}{4^2}\right] \quad \ldots(ii)$$

(ii)/(i), we get

$$\frac{\lambda_\alpha}{\lambda_e} = \left[\frac{\frac{1}{m^2} - \frac{1}{16}}{1 - \frac{1}{16}}\right] = \frac{1}{5}$$

$$\Rightarrow \frac{1}{m^2} - \frac{1}{16} = \frac{15}{16}\times\frac{1}{5}$$

$$\Rightarrow \frac{1}{m^2} - \frac{1}{16} = \frac{3}{16}, \Rightarrow \frac{1}{m^2} = \frac{3}{16} + \frac{1}{16}$$

$\Rightarrow m = 2$

From (ii)

$$\frac{hc}{\lambda_e} = 13.6\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = 13.6\times\frac{3}{16}\text{ev}$$

$$\Rightarrow \lambda_e = \frac{1242\times16}{13.6\times3}\text{nm} \Rightarrow \lambda_e \approx 487\ nm$$

We have $\text{KE}_a \propto \frac{z^2}{n^2} \Rightarrow \frac{KE_2}{KE_1} = \frac{1}{4}$

$$\Delta P_a = \frac{h}{\lambda_a};\ \Delta P_e = \frac{h}{\lambda_e}, \Rightarrow \frac{\Delta P_a}{\Delta P_e} = \frac{\lambda_e}{\lambda_a}$$

86. (*c*) $E = E_1 + E_2$

$$13.6(2)^2\left(\frac{1}{1^2} - \frac{1}{n^2}\right) = \frac{1240}{108.5} + \frac{1240}{30.4}$$

@FAKE_CBSE_X@RAJ_EDUNET

$\frac{25\times16}{36\times3}=488.9nm$

(a) We know that, $\frac{1}{\lambda}=R\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$;

$\frac{1}{\lambda_1}=R\left(\frac{1}{3^2}-\frac{1}{4^2}\right)\Rightarrow\frac{1}{\lambda_1}=R\left(\frac{7}{9\times16}\right)$;

$\frac{1}{\lambda_2}=R\left(\frac{1}{2^2}-\frac{1}{3^2}\right)\Rightarrow\frac{1}{\lambda_2}=R\left(\frac{5}{4\times9}\right)$

$\frac{\lambda_1}{\lambda_2}=\frac{5}{\frac{36}{7}}=\frac{5\times9\times16}{7\times36}=\frac{20}{7}$

For $M\to L$ steel

$K\left(\frac{1}{2^2}-\frac{1}{3^2}\right)=\frac{K\times5}{36}$

$K\to L$

$K\left(\frac{1}{2^2}-\frac{1}{4^2}\right)=\frac{K\times3}{16}\quad\lambda'=\frac{20}{27}\lambda$

$\frac{1}{\lambda}=R\left[\frac{1}{1}-\frac{1}{4^2}\right]$ ...(i)

$\frac{1}{\lambda'}=R\left[\frac{1}{m^2}-\frac{1}{4^2}\right]$ ...(ii)

Divide (ii) by (i) and get

$\frac{\lambda}{\lambda'}=\frac{R\left[\frac{1}{m^2}-\frac{1}{16}\right]}{R\left[\frac{1}{1}-\frac{1}{16}\right]}=\frac{1}{5}$

$\frac{1}{m^2}-\frac{1}{16}=\frac{15}{16}\times\frac{1}{5}$

$\frac{1}{m^2}=\frac{3}{16}+\frac{1}{16}$, $\Rightarrow\frac{1}{m^2}=\frac{3}{16}$,

$\frac{1}{\lambda'}=R\left[\frac{1}{m^2}-\frac{1}{4^2}\right]=13.6\times\frac{3}{16}$ ev

$\lambda'=\frac{16}{3}$ nm $\Rightarrow\lambda_e\approx487$ nm

$\frac{KE_2}{KE_1}=\frac{z^2}{n^2}\Rightarrow\frac{KE_2}{KE_1}=\frac{1}{4}$

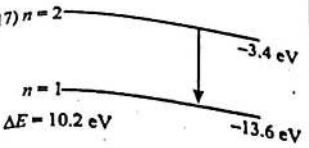
$\frac{\Delta P_e}{\Delta P_a}=\frac{h}{\lambda_e}$, $\Rightarrow\frac{\Delta P_e}{\Delta P_a}=\frac{\lambda_a}{\lambda_e}$

$\frac{1}{\lambda}=\frac{1240}{108.5}+\frac{1240}{30.4}$

$\left(1-\frac{1}{n^2}\right)=\frac{52.22}{54.4}$

$\frac{1}{n^2}=\frac{2.18}{54.4}\Rightarrow n^2=25\Rightarrow n=5$

87. (17)



Recoil speed $(v)=\frac{\Delta E}{mc}$

$=\frac{10.2\times1.6\times10^{-19}}{1.6\times10^{-27}\times3\times10^8}$

$v=3.4$ m/s $=\frac{17}{5}$ m/s

Therefore, $x=17$

88. (7) $\Delta E=\frac{hc}{\lambda}\Rightarrow\lambda=\frac{hc}{\Delta E}$

$\Delta E=13.6\left(\frac{1}{2^2}-\frac{1}{3^2}\right)=1.9eV$

As, $P_i=P_f\Rightarrow0=-mv+\frac{h}{\lambda'}$

$\Rightarrow v=\frac{h}{m\lambda'}$

Now, $\Delta E=\frac{1}{2}mv^2+\frac{hc}{\lambda'}$

$=\frac{1}{2}m\left(\frac{h}{m\lambda'}\right)^2+\frac{hc}{\lambda'}$

$\Rightarrow\Delta E=\frac{h^2}{2m\lambda'^2}+\frac{hc}{\lambda'}$

$\Rightarrow\lambda'=\frac{hc\pm\sqrt{h^2c^2+\frac{4\Delta Ehh^2}{2m}}}{2\Delta E}$

$\Rightarrow\lambda'=\frac{hc\pm hc\sqrt{1+\frac{2\Delta E}{mc^2}}}{2\Delta E}$

Now,

$\frac{\lambda'}{\lambda}=\frac{1+\left(1+\frac{2\Delta E}{mc^2}\right)^{\frac{1}{2}}}{2}=\frac{1+1+\frac{\Delta E}{mc^2}}{2}$

$\frac{\lambda'-\lambda}{\lambda}=\frac{\Delta E}{2mc^2}$

$=\frac{1.9\times1.6\times10^{-19}}{2\times1.67\times10^{-27}\times9\times10^{16}}=10^{-9}$

$\therefore$ % change $\approx10^{-7}$

89. (b) P.E. = 0 [For every large distance]

$\therefore$ Total energy = 2.6 + 0 = 2.6 eV

In 1st excited state of H, total energy = −3.4 eV

Thus loss in total energy = 6 eV

Frequency of emitted photon = $\frac{\text{Energy of photon}}{h}$

$=\frac{6\times1.6\times10^{-19}}{6.6\times10^{-34}}=1.45\times10^{15}$ Hz

$=1.45\times10^9$ mHz

90. [51]

$M_0=200MeV/C^2$, $m=1Gev/C^2$

Initial velocity of particle is 'V_0'.

Final velocity of hydrogen atom is 'V'

$M_0V_0=mV$

$V=\frac{M_0V_0}{m}$ ... (i)

Also, $\frac{1}{2}M_0V_0^2=\frac{1}{2}mV^2+\frac{3}{4}\times13.6$

Put (i) and get answer

$\frac{1}{2}M_0V_0^2=\frac{51}{4}eV$

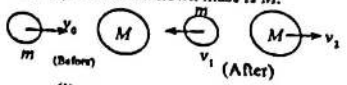
Hence, N = 51.

91. (b) $\frac{t_2}{t_1}=\frac{P_1}{P_2}\times\sqrt{\frac{T_2}{T_1}}$

$\frac{t_2}{t_1}=\frac{P}{2P}\times\sqrt{\frac{500}{300}}$

$t_2=\frac{6\times10^{-8}}{2}\times\sqrt{\frac{5}{3}}=4\times10^{-8}$ sec

92. (d) Let the unknown mass is M.



(i) $mv_0=-mv_1+Mv_2$

(ii) $v_0=v_1+v_2$

(iii) $\frac{2mv_0}{m+M}=v_2$

$KE_f=\frac{1}{2}mv_1^2=\frac{1}{2}m\left(\frac{M-m}{M+m}\right)^2v_0^2$

$=\frac{36}{100}\times\frac{1}{2}mv_0^2$

After solving above equation, $M=4$ m

93. (b) When a target metal is bombarded with high energy electron the X rays are emitted.

94. [10]

Given, $h=4.14\times10^{-15}$ eVs, $c=3\times10^8$ m/s

$E_{xd}=E_K-K_L$

$\Rightarrow\frac{h_c}{\lambda}=E_k-E_L\Rightarrow E_L=E_k-\frac{hc}{\lambda}$

Energy of the atom

$E_L=27.5-\frac{12.42\times10^{-7}}{0.071\times10^{-9}}$

$E_L=24.5-17.5=10$ keV

95. (a,c) $\lambda_{min}=\frac{hc}{eV}$

$\Rightarrow\lambda_{min}\propto\frac{1}{V}\Rightarrow(\lambda_{min})_{new}=\frac{\lambda_2}{2}$

$\because I=\frac{dN}{dt}\times\frac{hc}{\lambda}$ $\because\frac{dN}{dt}$ decreases

Hence I decreases

JEE-Advanced

1. (a) Electric potential between proton and electron in nth orbit is given as:

$V=V_o\ln\frac{r_n}{r_o}$

Thus, the Coulomb force

$|F_c|=e\frac{dV}{dr}=e\frac{V_0}{r_n}$

This Coulombic force is balanced by the centripetal force.

$\therefore\ \frac{mv^2}{r_n}=e\frac{V_o}{r_n}\Rightarrow v=\sqrt{\frac{eV_o}{m}}$

means that speed is constant

Now, from $mvr_n=\frac{nh}{2\pi}\Rightarrow r_n\propto n$ (as v = constant)

2. (d) For an atom following Bohr's model, the radius is given by $r_m=\frac{r_0m^2}{Z}$ where r_0 = Bohr's radius and m = orbit number. For $m=5$, (Fifth orbit in which the outermost electron is present)

$\therefore\ r_m=\frac{r_05^2}{100}=nr_0$ (given) $\Rightarrow n=\frac{1}{4}$

3. (c) In hydrogen atom, $E_n=-\frac{Rhc}{n^2}$.

Also, $E_n\propto m$

where, m is the mass of the electron.

Here, the electron has been replaced by a particle whose mass is double of an electron. Therefore, for this hypothetical atom energy in n^{th} orbit will be given by

$E_n=\frac{2Rhc}{n^2}$

The longest wavelength λ_{max} (or minimu

@FAKE_CBSE_X_@RJ_EDUFET

energy) photon will correspond to the transition of particle from $n = 3$ to $n = 2$.

$$\therefore \frac{hc}{\lambda_{max}} = E_3 - E_2 = 2Rhc\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

This gives, $\lambda_{max} = 18/5R$

4. (*d*) For hydrogen and hydrogen like atoms

$$E_n = -13.6\frac{(Z^2)}{(n^2)}\text{eV}$$

Therefore, ground state energy of doubly ionised lithium atom ($Z = 3$, $n = 1$)will be

$$E_1 = (-13.6)\frac{(3)^2}{(1)^2} = -122.4 \text{ eV}$$

$\therefore$ Ionisation energy of an electron in ground state of doubly ionised lithium atom will be 122.4 eV.

5. (*b, c*) $U = Fr$

[Using U = Potential energy and v = velocity, to avoid confusion between their symbols]

$$\Rightarrow \text{Force} = \frac{-dU}{dr} = -F$$

$\Rightarrow$ Magnitude of force = Constant = F

$$\Rightarrow F = \frac{mv^2}{R} \quad ...(i)$$

$$\Rightarrow mvR = \frac{nh}{2\pi} \quad ...(ii)$$

$$\Rightarrow F = \frac{m}{R} \times \frac{n^2h^2}{4\pi^2} \times \frac{1}{m^2R^2}$$

$$R = \left(\frac{n^2h^2}{4\pi^2mF}\right)^{1/3} \quad ...(iii)$$

$$\Rightarrow v = \frac{nh}{2\pi mR} \Rightarrow v = \frac{nh}{2\pi m}\left(\frac{4\pi^2mF}{n^2h^2}\right)^{1/3}$$

$$\Rightarrow v = \frac{n^{1/3}h^{1/3}F^{1/3}}{2^{1/3}\pi^{1/3}m^{2/3}} \quad ...(iv)$$

(*b*) is correct.

$$\Rightarrow E = \frac{1}{2}mv^2 + U = \frac{1}{2}mv^2 + FR$$

$$\Rightarrow E = \frac{1}{2}m\left(\frac{n^{2/3}h^{2/3}F^{2/3}}{2^{2/3}\pi^{2/3}m^{4/3}}\right) + F \times \left(\frac{n^2h^2}{4\pi^2mF}\right)^{1/3}$$

$$\Rightarrow E = \left(\frac{n^2h^2F^2}{4\pi^2m}\right)^{1/3}\left[\frac{1}{2} + 1\right] = \frac{3}{2}\left(\frac{n^2h^2F^2}{4\pi^2m}\right)^{1/3}$$

6. (*a, b, d*)Radius of the nth state

$$r_n = 0.529\frac{n^2}{Z_a} \Rightarrow r_n \propto \frac{n^2}{Z}$$

$$\therefore \frac{r_{n+1} - r_n}{r_n} \propto \frac{\frac{(n+1)^2}{Z} - \frac{n^2}{Z}}{\frac{n^2}{Z}}$$

OR $\frac{\Delta r_n}{r_n} \propto \frac{(n+1)^2 - n^2}{n^2} = \frac{2n+1}{n^2} = \frac{2}{n}$

($\because$ $2n + 1 = 2n$ for $n > 1$)

$\Rightarrow \frac{\Delta r_n}{r_n} \propto \frac{1}{n}$ and independent of Z

Thus, options (*a*) and (*b*) are correct.

Energy of nth state

$$E_n = -13.6\frac{Z^2}{n^2} \Rightarrow E_n \propto \frac{Z^2}{n^2}$$

$$\therefore \frac{E_{n+1} - E_n}{E_n} \propto \frac{\frac{Z^2}{(n+1)^2} - \frac{Z^2}{n^2}}{\frac{Z^2}{n^2}}$$

Or,

$$\frac{\Delta E_n}{E_n} \propto \frac{(n+1)^2 - n^2}{n^2} = \frac{2n+1}{n^2} = \frac{2}{n}$$

($\because$ $2n + 1 = 2n$ and $n + 1 = n$ for $>> 1$)

$\Rightarrow \frac{\Delta E_n}{E_n} \propto \frac{1}{n}$ and independent of Z

Thus option (*c*) is wrong.

Angular momentum $L_n = n\hbar$

$$\therefore \frac{\Delta L_n}{L_n} = \frac{(n+1)\hbar - n\hbar}{n\hbar} = \frac{1}{n}$$

$$\Rightarrow \frac{\Delta L_n}{L_n} \propto \frac{1}{n}$$

7. (*a, c*) Given data:

$$4.5a_0 = a_0\frac{n^2}{Z} \quad ...(i)$$

$$\frac{nh}{2\pi} = \frac{3h}{2\pi} \quad ...(ii)$$

So, $n = 3$ and $z = 2$

So, possible wavelength are

$$\frac{1}{\lambda_1} = RZ^2\left[\frac{1}{1^2} - \frac{1}{3^2}\right] \Rightarrow \lambda_1 = \frac{9}{32R}$$

$$\frac{1}{\lambda_2} = RZ^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right] \Rightarrow \lambda_2 = \frac{1}{3R}$$

$$\frac{1}{\lambda_3} = RZ^2\left[\frac{1}{2^2} - \frac{1}{3^2}\right] \Rightarrow \lambda_3 = \frac{9}{5R}$$

8. (*a, c, d*) $r_n \propto \frac{n^2}{Z}$ and $|PE| = 2(KE)$

9. (*d*) $L = I\omega = \frac{nh}{2\pi} \Rightarrow \omega = \frac{nh}{2\pi I}$

$$K = \frac{1}{2}I\omega^2 = \frac{1}{2}I\left(\frac{nh}{2\pi I}\right)^2 = \frac{n^2h^2}{8\pi^2I}$$

10. (*b*) $hf = K_2 - K_1 = \frac{(2)^2h^2}{8\pi^2I} - \frac{(1)^2h^2}{8\pi^2I} = \frac{3h^2}{8\pi^2I}$

$$\therefore I = \frac{3h}{8\pi^2f} = \frac{3 \times 2\pi \times 10^{-34} \times \pi}{8 \times \pi^2 \times 4 \times 10^{11}}$$

$= 1.87 \times 10^{-46}$ kg-m^2

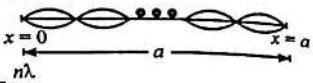
11. (*c*) $I = \mu r^2$ (where, μ = reduced mass)

$$m = \frac{m_1m_2}{m_1 + m_2} = \frac{48}{7} \text{ amu} = 11.43 \times 10^{-27} \text{ kg}$$

Substituting in $I = \mu r^2$ we get,

$$r = \sqrt{\frac{I}{\mu}} = \sqrt{\frac{1.87 \times 10^{-46}}{11.43 \times 10^{-27}}} = 1.28 \times 10^{-10} \text{ m}$$

12. (*a*)



$$a = \frac{n\lambda}{2}$$

$$\therefore \lambda = \frac{2a}{n} = \frac{h}{p} = \frac{h}{\sqrt{2Em}} \quad ...(i)$$

$$\sqrt{E} \propto \frac{1}{a} \Rightarrow E \propto \frac{1}{a^2}$$

13. (*b*) From Eq. (*i*) $E = \frac{n^2h^2}{8a^2m}$

In ground state $n = 1$

$$\therefore E_1 = \frac{h^2}{8ma^2}$$

Substituting the values, we get

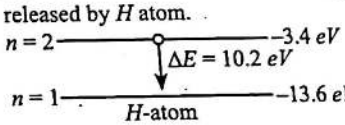
$E_1 = 8$ meV

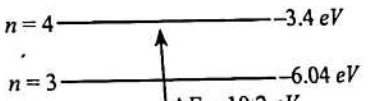
14. (*d*) From Eq. (*i*) $p \propto n$

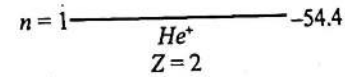
$\therefore$ $mv \propto n$ or $v \propto n$

15. (*c*) Subsequently H atoms transfer their total excitation energy to He^+ ions (by collisions) Assume that the bohr model of atoms is exactly valid. The quantum number n of the state finally populated in He^+ ions is

$\Delta E = h\nu = 34 \times 13.6$ eV = Energy released by H atom.







Energy given by H-atom in transition from $n = 2$ to $n = 1$ is equal to energy taken by He^+ atom in transition from $n = 2$ to $n = 4$.

@CBSE_X@RAJ_EDUNET

16. (c) The wavelength corresponding to transition from $n = 4$ to $n = 3$ in He^+ corresponds to the visible region. Its wavelength is:

$$\frac{hc}{\lambda} = 13.6 \times 4\left[\frac{1}{9} - \frac{1}{16}\right]$$

$$\frac{4.1\times10^{-15}\times3\times10^{8}}{\lambda(m)} = 13.6\times4\times\frac{7}{9\times16}$$

$$\Rightarrow \lambda = \frac{4.1\times10^{-15}\times3\times10^{8}}{13.6\times4\times\frac{7}{9\times16}}\,m$$

$$\Rightarrow \lambda = 4.68\times10^{-7}\,m$$

17. (a) K·E· = −T·E

$$\frac{K_H}{K_{He}} = \frac{TE_H}{TE_{He}}$$

For same 'n': $\frac{TE_H}{TE_{He}} = \frac{(Z_H)^2}{(Z_{He})^2} = \frac{1}{4}$

18. [2] Angular momentum $= n\left(\frac{h}{2\pi}\right) = 3\left(\frac{h}{2\pi}\right)$

$\therefore\ n = 3,\ r_n \propto \frac{n^2}{z}$

$\therefore\ r_3 = \frac{(3)^2}{3}(a_0) = 3a_0$

Now, $mv_3r_3 = 3\left(\frac{h}{2\pi}\right)$

$\therefore\ mv_3(3a_0) = 3\left(\frac{h}{2\pi}\right)$

or $\frac{h}{mv_3} = 2\pi a_0$ or $\frac{h}{P_3} = 2\pi a_0\ (\because P = mv)$

or $\lambda_3 = 2\pi a_0 \qquad \left(\lambda = \frac{h}{P}\right)$

$\therefore$ Answer is 2.

19. Kinetic energy of an electron in n^{th} orbit of hydrogen atom is $K = \frac{me^4}{8\varepsilon_0^2h^2n^2}$

$$E = -\frac{me^4}{8\varepsilon_0^2h^2n^2},\ \frac{K}{E} = -1 \text{ or } K = -E$$

20. Kinetic energy of ejected electron = Energy of incident photon-energy required to ionize the electron from n^{th} orbit

$$\therefore\ 10.4 = \frac{1242}{90} - |E_n| = \frac{1242}{90} - \frac{13.6}{n^2}$$

$$\left(as\ E_n \propto \frac{1}{n^2}\ and\ E_1 = -13.6eV\right)$$

Solving this equation, we get $n = 2$

21. (a) Let B_2 be the hydrogen-like atom. Let x be the quantum no. difference of the states.

$x + 1_{B_2} = 6 \Rightarrow x = 3$

Now, we have $-z^2\frac{(13.6eV)}{n^2} = -0.85eV$ ...(i)

$-z^2\frac{(13.6eV)}{(n+3)^2} = -0.544eV.$

Solving (i) & (ii), we get

$n = 12,\ z = 3$

(b) Smallest wavelength λ is given as

$\frac{hc}{\lambda} = (0.85 - 0.544)eV$ ...(iii)

when, h = Plank's constant $= 6.626\times10^{-34}\ m^2\ kg/s$

From (iii)

$\Rightarrow \lambda = 4052\ nm$

22. (a) Total 6 lines are emitted. Therefore,

$\frac{n(n-1)}{2} = 6$ or $n = 4$

So, transition is taking place between m^{th} energy state and $(m + 3)^{th}$ energy state.

$E_m = -0.85$ eV

or $-13.6\left(\frac{z^2}{m^2}\right) = -0.85$

or $\frac{z}{m} = 0.25$ ...(i)

Similarly, $E_{m+3} = -0.544$ eV

or $-13.6\frac{z^2}{(m+3)^2} = 0.544$

or $\frac{z}{(m+3)} = 0.2$ ...(ii)

Solving Eqs. (i) and (ii) for z and m, we get

$m = 12$ and $z = 3$

(b) Smallest wavelength corresponds to maximum difference of energies which is obviously $E_{m+3} - E_m$

$\therefore\ \Delta E_{max} = -0.544 - (-0.85)$

$= 0.306$ eV

$\therefore\ \lambda_{min} = \frac{hc}{\Delta E_{max}} = \frac{1240}{0.306}$

$= 4052.3$ nm.

23. (a) Given, $E_3 - E_2 = -47.2$ eV

Since $E_n \propto \frac{Z^2}{n^2}$

(for hydrogen like atoms)

or $(-13.6)\left(\frac{Z^2}{9}\right) - \left[(-13.6)\left(\frac{Z^2}{4}\right)\right]$

$= 47.2$ eV

Solving this equation, we get

$Z = 5$

(b) Energy required to excite the electron from 3rd to 4th orbit:

$E_{3\to4} = E_4 - E_3$

$= (-13.6)\left(\frac{25}{16}\right) - \left[(-13.6)\left(\frac{25}{9}\right)\right]$

$= 16.54$ eV

(c) Energy required to remove the electron from first orbit to infinity (or the ionisation energy) will be

$E = (13.6)\ (5)^2 = 340$ eV

The corresponding wavelength would be,

$\lambda = \frac{hc}{E} = \frac{6.6\times10^{-34}\times3\times10^{8}}{340\times1.6\times10^{-19}}$

$= 0.0364\times10^{-7}\ m = 36.4$ Å

(d) In first orbit, total energy $= -340$ eV

kinetic energy $= +340$ eV

Potential energy $= -2\times340$ eV

$= -680$ eV and angular momentum

$= \frac{h}{2\pi} = \frac{6.6\times10^{-34}}{2\pi}$

$= 1.05\times10^{-34}$ kg-m²/s

(e) $r_n \propto \frac{n^2}{Z}$

Radius of first Bohrs orbit

$r_1 = \frac{r_1^H}{Z} = \frac{5.3\times10^{-11}}{5} = 1.06\times10^{-11}$ m

24. (a) 1 rydberg $= 2.2\times10^{-18}\ J = Rhc$

Ionisation energy is given as 4 rydberg

$= 8.8\times10^{-18}\ J = \frac{8.8\times10^{-18}}{1.6\times10^{-19}} = 55$ eV

$\therefore$ Energy in first orbit $E_1 = -55$ eV

Energy of radiation emitted when electron jumps from first excited state ($n = 2$) to ground state ($n = 1$):

$E_{21} = \frac{E_1}{(2)^2} - E_1 = -\frac{3}{4}E_1 = 41.25$ eV

$\therefore$ Wavelength of photon emitted in this transition would be

$\lambda = \frac{12375}{41.25} = 300$ Å

(b) Let Z be the atomic number of given element. Then

$E_1 = (-13.6)\ (Z^2)$

or $-55 = (-13.6)\ (Z^2)$ or $Z \approx 2$

Now, as $r \propto \frac{1}{Z}$

Radius of first orbit of this atom,

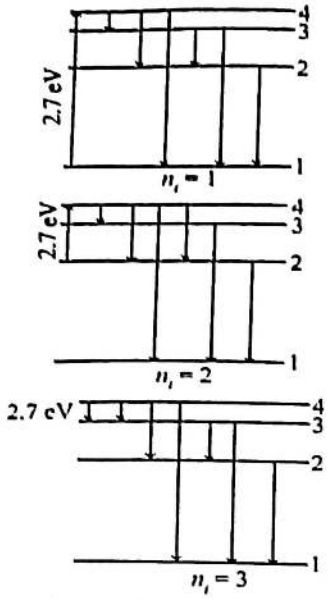
$r_1 = \frac{r_{H_1}}{Z} = \frac{0.529}{2}$ Å $= 0.2645$ Å

25. (a) In emission spectrum total six lines are obtained. Hence, after excitation if n_f be the final principal quantum number then,

$\frac{n_f(n_f-1)}{2} = 6$ or $n_f = 4$

i.e. after excitation atom goes to 4th energy state. Hence, n_i can be either 1, 2 or 3.

@FAKE_CBSE_X @RAJ_EDUNET



Absorption and emission spectrum corresponding to

$n_i = 1$, $n_i = 2$ and $n_i = 3$ are shown in figure.

For $n_i = 1$, energy of emitted photons ≤ 2.7 eV

For $n_i = 2$, energy of emitted photons $\geq\!=\!< 2.7$ eV and

For $n_i = 3$, energy of emitted photons ≥ 2.7 eV.

As per the given condition $n_i = 2$.

(*b*) $E_4 - E_2 = 2.7$ eV

or $\frac{E_1}{16} - \frac{E_1}{4} = 2.7$

or $-\frac{3}{16}E_1 = 2.7$

$E_1 = -14.4$ eV

Therefore, ionization energy for the gas atoms is $|E_1|$ or 14.4 eV.

(*c*) Maximum energy of the emitted photons is corresponding to transition from $n = 4$ to $n = 1$.

$\therefore E_{max} = E_4 - E_1 = \frac{E_1}{16} - E_1 = \frac{15E_1}{16}$

$= \left(-\frac{15}{16}\right)(14.4) = 13.5$ eV

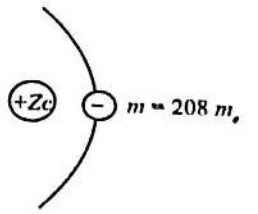
Similarly, minimum energy of the emitted photons is corresponding to transition from $n = 4$ to $n = 3$.

$\therefore E_{min} = E_4 - E_3$

$= \frac{E_1}{16} - \frac{E_1}{9} = -\frac{7E_1}{16\times 9}$

$= \frac{7\times 14.4}{16\times 9} = 0.7$ eV

26. If we assume that mass of nucleus >> mass of mu-meson, then nucleus will be assumed to be at rest, only mu-meson is revolving round it.



(*a*) In n^{th} orbit the necessary centripetal force to the mu-meson will be provided by the electrostatic force between the nucleus and the mu-meson.

Hence,

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{r^2} \quad ...(i)$$

Further, it is given that Bohr model is applicable to this system also. Hence

Angular momentum in n^{th} orbit $= \frac{nh}{2\pi}$

or $mvr = n\frac{h}{2\pi}$ ...(*ii*)

We have two unknowns v and r (in n^{th} orbit).

After solving these two equations, we get

$$r = \frac{n^2h^2\varepsilon_0}{Z\pi me^2}$$

Substituting $Z = 3$ and $m = 208m_e$, we get

$$r_n = \frac{n^2h^2\varepsilon_0}{624\pi m_e e^2}$$

(*b*) The radius of the first Bohrs orbit for the hydrogen atom $\frac{h^2\varepsilon_0}{\pi m_e e^2}$.

Equating this with the radius calculated in part (*a*), we get

$n^2 \approx 624$ or $n \approx 25$

(*c*) Kinetic energy of atom $= \frac{mv^2}{2} = \frac{Ze^2}{8\pi\varepsilon_0 r}$

and potential energy $= -\frac{Ze^2}{4\pi\varepsilon_0 r}$

$\therefore$ Total energy $E_n = \frac{-Ze^2}{8\pi\varepsilon_0 r}$

Substituting value of r, calculated in part (*a*),

$$E_n = \frac{1872}{n^2}\left[-\frac{m_e e^4}{8\varepsilon_0^2 h^2}\right]$$

But $\left[-\frac{m_e e^4}{8\varepsilon_0^2 h^2}\right]$ is the ground state energy of hydrogen atom and hence is equal to -13.6 eV.

$\therefore E_n = \frac{-1872}{n^2}(13.6) = \frac{25459.2}{n^2}$ eV

$\therefore E_3 - E_1 = -25459.2\left[\frac{1}{9} - \frac{1}{1}\right]$

$= 22630.4$ eV

$\therefore$ The corresponding wavelength,

λ (in Å) $= \frac{12375}{22630.4} = 0.546$Å

27. (*b*) K_α transition takes place from $n_1 = 2$ to $n_2 = 1$

$\therefore \frac{1}{\lambda} = R(Z-b)^2\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right]$

For K-series, $b = 1$

$\therefore \frac{1}{\lambda} \propto (Z-1)^2 \Rightarrow \frac{\lambda_{Cu}}{\lambda_{Mo}} = \frac{(z_{Mo}-1)^2}{(z_{Cu}-1)^2}$

$= \frac{(42-1)^2}{(29-1)^2} = \frac{41\times 41}{28\times 28} = \frac{1681}{784} = 2.144$

28. (*b*) $\frac{1}{\lambda} = R\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right]$

The largest wavelength in the ultraviolet region of the hydrogen spectrum corresponds to the transition $n_1 = 2$ to $n_2 = 1$ (Lyman series).

Thus, $\frac{1}{122\,nm} = R\left[1 - \frac{1}{4}\right] = \frac{3R}{4}$

Which gives us, $R = \frac{4}{3\times 122\,nm}$

The smallest wavelength λ in the infrared region of the hydrogen spectrum corresponds to $n_1 = \infty$ and $n_2 = 3$ (Paschen series).

Therefore, $\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{\infty}\right] = \frac{R}{9}$

$\Rightarrow \lambda = \frac{9}{R} = \frac{9\times 3\times 122\,nm}{4} = 823\,nm$

29. (*a*) $\frac{1}{\lambda} \propto (Z-1)^2$

$\therefore \frac{\lambda_1}{\lambda_2} = \left(\frac{Z_2-1}{Z_1-1}\right)^2$ or $\frac{1}{4} = \left(\frac{Z_2-1}{11-1}\right)^2$

Solving this, we get $Z_2 = 6$

30. (*b*) In second excited state $n = 3$,

So, $l_H = l_{Li} = 3\left(\frac{h}{2\pi}\right)$.

while $E \propto Z^2$ and $Z_H = 1$, $Z_{Li} = 3$

So, $|E_{Li}| = 9|E_H|$ or $|E_H| < |E_{Li}|$

31. (*d*) Energy of infrared radiation is less than the energy of ultraviolet radiation. In options (*a*), (*b*) and (*c*), energy released will be more, while in option (*d*) only, energy released will be less.

@FAKE_CBSE_X@RAJ_EDUNET

...0.4 eV ...2$\left[\frac{1}{9}-\frac{1}{1}\right]$

he corresponding wavelength

(in Å) $= \frac{12375}{22630.4} = 0.546$ Å

ısition takes place from $n_2 = 2$ to

$R(Z-b)^2\left[\frac{1}{(1)^2}-\frac{1}{(2)^2}\right]$

eries, $b = 1$

$(Z-1)^2 \Rightarrow \frac{\lambda_{Cu}}{\lambda_{Mo}} = \frac{(z_{Mo}-1)^2}{(z_{Cu}-1)^2}$

$)^2 = \frac{41\times41}{28\times28} = \frac{1681}{784} = 2.144$

$\left[\frac{1}{n_1^2}\right]$

wavelength in the ultraviolet the hydrogen spectrum s to the transition $n_1 = 2$ to an series).

$\frac{1}{\lambda} = R\left[1-\frac{1}{4}\right] = \frac{3R}{4}$

us, $R = \frac{4}{3\times122nm}$

t wavelength λ in the ion of the hydrogen esponds to $n_1 = \infty$ and n series).

$= R\left[\frac{1}{3^2}-\frac{1}{\infty}\right] = \frac{R}{9}$

$\frac{3\times122nm}{4} = 823nm$

$\Big)^2$ or $\frac{1}{4} = \left(\frac{Z_2-1}{11-1}\right)^2$

et $Z_2 = 6$

state $n = 3$,

$1, Z_{Li} = 3$

$< |E_{Li}|$

adiation is less than iolet radiation. In c), energy released in option (d) only, be less.

32. (a) $v_n \propto \frac{1}{n}$ $\therefore$ KE $\propto \frac{1}{n^2}$ (with positive sign)

potential energy U is negative and $U_n \propto \frac{1}{r_n}$

$\left[U_n = -\frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2}{r_n}\right]$

$E_n \propto \frac{1}{n^2}$ (because $r_n \propto n^2$)

Similarly, total energy $E_n \propto \frac{1}{n^2}$ (with negative sign)

33. (b) Since, the wavelength (λ) is increasing, we can say that the galaxy is receding. Doppler effect (in E-M wave) can be given by

$\lambda' = \lambda\sqrt{\frac{c+v}{c-v}}$ ...(i)

or $706 = 656\sqrt{\frac{c+v}{c-v}}$

or $\frac{c+v}{c-v} = \left(\frac{706}{656}\right)^2 = 1.16$

$\therefore\ c+v = 1.16c - 1.16v$

$\therefore\ v = \frac{0.16c}{2.16} = \frac{0.16\times3.0\times10^8}{2.16}$

$= 0.22 \times 10^8$ m/s, $v \approx 2.2 \times 10^7$ m/s

34. (d) Shortest wavelength will correspond to maximum energy. As value of atomic number (Z) increases, the magnitude of energy in different energy states gets increased. Value of Z is maximum for doubly ionised lithium atom ($Z = 3$) among the given elements. Hence, wavelength corresponding to this will be least.

35. (c) Beta particles are fast moving electrons which are emitted by the nucleus.

36. (c) During fusion process two or more lighter nuclei combine to form a heavy nucleus.

37. (a, d) For hydrogen atom, $z = 1$

$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$,

where $R = 1.0973 \times 107\ m^{-1}$ = Rydberg constant.

For the Lyman series, $n_1 = 1$ and $n_2 = 2, 3, 4,$

$\frac{1}{\lambda} = R\left(1-\frac{1}{n_2^2}\right)$

$\lambda = \lambda_{max}$, when $n_2 = 2$

$\frac{1}{\lambda_{max}} = \frac{3R}{4} \Rightarrow \lambda_{max} = \frac{4}{3R} = 121.5$ nm

$\lambda = \left(\frac{n_i^2}{n_i^2-1}\right)\frac{1}{R} = \left[1+\frac{1}{(n_i^2-1)}\right]\lambda_0 = \left(1+\frac{1}{m^2}\right)\lambda_0$

$\lambda = \left(1+\frac{1}{m^2}\right)\lambda_0$

where,

$m^2 = (n_i^2-1)$ = an integer

$m = \sqrt{n_i^2-1}$ = not an integer

For the Balmer series, $n_1 = 2$ and $n_2 = 3,$ $4, 5, 6, \ldots\ldots \infty$ $\frac{1}{\lambda} = R\left(\frac{1}{4}-\frac{1}{n_i^2}\right)$

$\lambda = \lambda_{max}$, when $n_2 = 3$

$\frac{1}{\lambda_{max}} = \frac{5R}{36}$

$\lambda_{max} = \frac{36}{5R} = 656.2$ nm

$\lambda = \lambda_{min}$, when $n_2 = \infty$

$\Rightarrow \lambda_{min} = \frac{4}{R} = 364.5$ nm

Hence, for the Balmer series,

$\frac{\lambda_{max}}{\lambda_{min}} = \frac{36/5R}{4/R} = \frac{9}{5}$

For the Paschen series, $n_1 = 3$ and $n_2 = 4, 5, 6, \ldots\ldots \infty$

$\frac{1}{\lambda} = R\left(\frac{1}{9}-\frac{1}{n_2^2}\right)$

$\lambda = \lambda_{max}$, when $n_2 = 4$

$\frac{1}{\lambda_{max}} = R\left(\frac{1}{9}-\frac{1}{16}\right) = \frac{7R}{144}$

$\Rightarrow \lambda_{max} = \frac{144}{7R} = 1874.7$ nm

$\lambda = \lambda_{min}$, when $n_2 = \infty$

$\frac{1}{\lambda_{min}} = \frac{R}{9} \Rightarrow \lambda_{min} = \frac{9}{R} = 820.2$ nm

38. (b,c) $\frac{hc}{\lambda_\alpha} = 13.6\left[\frac{1}{1}-\frac{1}{4^2}\right]$ ...(i)

$\frac{hc}{\lambda_e} = 13.6\left[\frac{1}{m^2}-\frac{1}{4^2}\right]$ ...(ii)

From (ii)/(i), we get

$\frac{\lambda_\alpha}{\lambda_e} = \left[\frac{\frac{1}{m^2}-\frac{1}{16}}{1-\frac{1}{16}}\right] = \frac{1}{5}$

$\Rightarrow \frac{1}{m^2}-\frac{1}{16} = \frac{15}{16}\times\frac{1}{5}$

$\Rightarrow \frac{1}{m^2}-\frac{1}{16} = \frac{3}{16}$

$\Rightarrow \frac{1}{m^2} = \frac{3}{16}+\frac{1}{16}$

$\Rightarrow m = 2$

From (ii)

$\frac{hc}{\lambda_e} = 13.6\left[\frac{1}{2^2}-\frac{1}{4^2}\right] = 13.6\times\frac{3}{16}$ ev

$\Rightarrow \lambda_e = \frac{1242\times16}{13.6\times3}$ nm

$\Rightarrow \lambda_e = 487$ nm

We have $KE_n \propto \frac{z^2}{n^2}$

$\Rightarrow \frac{KE_2}{KE_1} = \frac{1}{4}$

$\Delta P_\alpha = \frac{h}{\lambda_\alpha}$; $\Delta P_e = \frac{h}{\lambda_e}$

$\Rightarrow \frac{\Delta P_\alpha}{\Delta P_e} = \frac{\lambda_e}{\lambda_\alpha}$

39. [3] $\Delta E_{2-1} = 13.5 \times Z^2\left[1-\frac{1}{4}\right]$

$= 13.6 \times Z^2\left[\frac{3}{4}\right]$

$\Delta E_{3-2} = 13.6 \times Z^2\left[\frac{1}{4}-\frac{1}{9}\right]$

$= 13.6 \times Z^2\left[\frac{5}{36}\right]$

$\therefore\ \Delta E_2 = \Delta E_{3-2} + 74.8$

$40.....6 \times Z^2\left[\frac{3}{4}\right]$

$= 13.6 \times Z^2\left[\frac{5}{36}\right] + 74.8$

$41.....6 \times Z^2\left[\frac{3}{4}-\frac{5}{36}\right] = 74.8$

$Z^2 = 9$

$\therefore\ Z = 3$

40. [5] Potential energy of hydrogen atom ($Z = 1$) in the n^{th} orbit (in eV)

$PE = -\frac{27.2}{n^2}\frac{v_f}{v_i} = \frac{-\frac{27.2}{n_f^2}}{-\frac{27.2}{n_i^2}} = \frac{1}{6.25}$

$6.25 = \frac{n_f^2}{n_i^2}$

$\frac{n_f}{n_i} = 2.5 = \frac{5}{2}$

@FAKE_CBSE_X_@RAJ_EDUNET

41. [6] Energy of incident light (in eV)

$$E = \frac{12375}{970} = 12.7 \text{ eV}$$

After excitation, let the electron jumps to n^{th} state, then

$$\frac{-13.6}{n^2} = -13.6 + 12.7$$

Solving this equation, we get

$n = 4$

$\therefore$ Total number of lines in emission spectrum,

$$= \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$$

42. K_α corresponds to $n = 2$ to $n = 1$

and K_β corresponds to $n = 3$ to $n = 1$

$$\frac{1}{\lambda_K} = R(z-b)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$b = 1$ for K-series

$$\lambda_K \propto \frac{1}{\frac{1}{n_1^2} - \frac{1}{n_2^2}}$$

Since, $E_{31} > E_{21}$

$$\therefore \quad \lambda_{K_\beta} < \lambda_{K_\alpha} \text{ or } \lambda_{K_\beta} = \lambda_{K_\alpha}\left[\frac{\frac{1}{1^2} - \frac{1}{2^2}}{\frac{1}{1^2} - \frac{1}{3^2}}\right]$$

$$= 0.32\left(\frac{3/4}{8/9}\right) = 0.27\text{Å}$$

43. From conservation of linear momentum,

|Momentum of recoil hydrogen atom| = |Momentum of emitted photon|

or $mv = \frac{\Delta E}{c}$

Here, $\Delta E = E_5 - E_1 = -13.6\left[\frac{1}{5^2} - \frac{1}{1^2}\right]$ eV

$= (13.6)\,(24/25)$ eV $= 13.056$ eV

$= 13.056 \times 1.6 \times 10^{-19}\text{J} = 2.09 \times 10^{-18}\text{J}$

and m = mass of hydrogen atom $= 1.67 \times 10^{-27}$ kg

$$\therefore \quad v = \frac{\Delta E}{mc} = \frac{2.09 \times 10^{-18}}{(1.67 \times 10^{-27})(3 \times 10^8)} = 4.17\, m/s$$

44. Wavelengths corresponding to minimum wavelength (λ_{min}) or maximum energy will emit photoelectrons having maximum kinetic energy.

Energy of photon of wavelength 450 nm is $\frac{1242}{450}$ or 2.76 eV

Similarly of wavelength 750 nm is $\frac{1242}{750}$ or 1.656 eV.

(λ_{min}) belonging to Balmer series and lying in the given range (450 nm to 750 nm) corresponds to transition from ($n = 4$ to $n = 2$). Here,

$$E_4 = -\frac{13.6}{(4)^2} = -0.85 \text{ eV}$$

and $E_2 = -\frac{13.6}{(2)^2} = -3.4$ eV

$\therefore \quad \Delta E = E_4 - E_2 = 2.55$ eV

K_{max} = Energy of photon − work function

$= 2.55 - 2.0 = 0.55$ eV

45. A hydrogen like atom of atomic number Z is in an excited state of quantum number $2n$. It can emit a maximum energy photon of $204eV$. if it makes a transition to quantum state n, then a photon of energy $40.8eV$ is emitted.

Let ground state energy (in) be E_1.

Then, from the given condition

or $E_{2n} - E_1 = 204eV \quad \frac{E_1}{4n^2} - E_1 = 204eV$

or $E_1\left(\frac{1}{4n^2} - 1\right) = 204eV \quad \ldots(i)$

and $E_{2n} - E_n = 40.8eV$

or $\frac{E_1}{4n^2} - \frac{E_1}{n^2} = 40.8eV$

or $E_1\left(\frac{-3}{4n^2}\right) = 40.8eV \quad \ldots(ii)$

From Eqs. (i) and (ii),

$$\frac{1 - \frac{1}{4n^2}}{\frac{3}{4n^2}} = 5 \text{ or } 1 = \frac{1}{4n^2} + \frac{15}{4n^2} \text{ or } \frac{4}{n^2} = 1$$

$n = 2$ or $n = 2$

From Eq. (ii),

$$E_1 = -\frac{4}{3}n^2(40.8)eV = -\frac{4}{3}(2)^2(40.8)eV$$

or $E_1 = -217.6eV \; E_1 = -(13.6)Z^2$

$$Z^2 = \frac{E_1}{-13.6} = \frac{-217.6}{-13.6} = 16$$

$Z = 4$

$$E_{min} = E_{2n} - E_{2n-1} = \frac{E_1}{4n^2} - \frac{E_1}{(2n-1)^2}$$

$$= \frac{E_1}{16} - \frac{E_1}{9} = -\frac{7}{144}E_1 = -\left(\frac{7}{144}\right)(-217.6)eV$$

$\therefore \quad E_{min} = 10.58eV$

46. From the given conditions

$E_n - E_2 = (10.2 + 17)\text{eV} = 27.2\text{eV} \quad \ldots(i)$

and $E_n - E_3 = (4.25 + 5.95)\text{eV} = 10.2$ eV $\quad \ldots(ii)$

Eq. (i) − Eq. (ii) gives

$E_3 - E_2 = -17.0$ eV

or $Z^2(13.6)\left(\frac{1}{4} - \frac{1}{9}\right) = 17.0$

Solving this equation, we get

$Z = 3$

From Eq. (i) $Z^2\,(13.6)\left(\frac{1}{4} - \frac{1}{n^2}\right) = 27.2$

or $(3)^2\,(13.6)\left(\frac{1}{4} - \frac{1}{n^2}\right) = 27.2$

Solving this equation, we get

$n = 6$

47. Energy corresponding to given wavelength

$$E(\text{in eV}) = \frac{12375}{\lambda(\text{in Å})} = \frac{12375}{975} = 12.69\text{ eV}$$

Now, let the electron excites to n^{th} energy state. Then,

$$E_n - E_1 = 12.67 \text{ or } \frac{(-13.6)}{(n^2)} - (-13.6)$$

$= 12.69$

$\therefore \quad n \approx 4$

i.e. electron excites to 4th energy state.

Total number of lines in emission spectrum would be

$$\frac{n(n-1)}{2} = \frac{4 \times 3}{2} = 6$$

Longest wavelength will correspond to the minimum energy and minimum energy is released in transition from $n = 4$ to $n = 3$.

$$E_{4-3} = E_4 - E_3 = \frac{-13.6}{(4^2)} - \left[\frac{-13.6}{(3)^2}\right] = 0.66\text{ eV}$$

$\therefore$ Longest wavelength will be,

$$\lambda_{max} = \frac{12375}{E(\text{in eV})}$$

$$= \frac{12375}{0.66}\text{Å} = 1.875 \times 10^{-6}\text{ m}$$

$= 1.875\ \mu\text{m}$

48. When 800 Å wavelength falls on hydrogen atom (in ground state) 13.6 eV energy is used in liberating the electron. The rest goes to kinetic energy of electron.

Hence, $K = E - 13.6$ (in eV) or

$(1.8 \times 1.6 \times 10^{-19})$

$$= \frac{hc}{800 \times 10^{-10}} - 13.6 \times 1.6 \times 10^{-19} \quad \ldots(i)$$

Similarly, for the second wavelength:

$(4.0 \times 1.6 \times 10^{-19})$

$$= \frac{hc}{700 \times 10^{-10}} - 13.6 \times 1.6 \times 10^{-19} \quad \ldots(ii)$$

Solving these two equations, we get

$h \approx 6.6 \times 10^{-34}$ J-s

@FAKE_CBSE_@RAJ_EDUNET

ation, we get

rom Eq. (i) $Z^2 (13.6)\left(\frac{1}{4}-\frac{1}{n^2}\right) = 27.2$

$(3)^2 (13.6)\left(\frac{1}{4}-\frac{1}{n^2}\right) = 27.2$

lving this equation, we get

6

rgy corresponding to given wavelength

1 eV) $= \frac{12375}{\lambda(\text{in Å})} = \frac{12375}{975} = 12.69$ eV

let the electron excites to n^{th} energy

Then,

$= 12.67$ or $\frac{(-13.6)}{(n^2)} - (-13.6)$

$= 12.69$

4

ctron excites to 4th energy state.

umber of lines in emission spectrum

e

$= \frac{4\times3}{2} = 6$

wavelength will correspond to the

energy and minimum energy is

a transition from $n = 4$ to $n = 3$.

$- E_3 = \frac{-13.6}{(4^2)} - \left[\frac{-13.6}{(3)^2}\right] = 0.66$ eV

it wavelength will be,

$\frac{12375}{E(\text{in eV})}$

;

$-$ Å $= 1.875 \times 10^{-6}$ m

um

wavelength falls on hydrogen

und state) 13.6 eV energy is

ing the electron. The rest goes

gy of electron.

$- 13.6$ (in eV) or

$^{-19}$)

$- 13.6 \times 1.6 \times 10^{-19}$ ...(i)

e second wavelength:

^{19})

$13.6 \times 1.6 \times 10^{-19}$ ...(ii)

o equations, we get

^{34} J-s

49. Given $Z = 3$, $E_n \propto \frac{Z^2}{n^2}$

(a) To excite the atom from $n = 1$ to $n = 3$, energy of photon required is

$\Delta E = E_3 - E_1$

$= \frac{(-13.6)(3)^2}{(3)^2} - \left[\frac{-(13.6)(3)^2}{(1)^2}\right]$

$= 108.8$ eV

Corresponding wavelength will be,

$\lambda(\text{in Å}) = \frac{12375}{\Delta E(\text{in eV})} = \frac{12375}{108.8}$

$= 113.74$ Å

(b) From n^{th} orbit total number of emission lines can be $\frac{n(n-1)}{2}$.

$\therefore$ Number of emission lines

$= \frac{3(3-1)}{2} = 3$

50. (b) Cut-off wavelength depends on the applied voltage not on the atomic number of the target. Characteristic wavelengths depend on the atomic number of target.

51. (d) Minimum wavelength of continuous X-ray spectrum is given by λ_{min} (in Å)

$= \frac{12375}{E(\text{in eV})}$

Here E = energy of incident electrons (in eV) = energy corresponding to minimum wavelength λ_{min} of X-rays.

$E = 80$ keV $= 80 \times 10^3$ eV

$\therefore \lambda_{min}$ (in Å) $= \frac{12375}{80\times10^3} = 0.155$

Also the energy of the incident electrons (80 keV) is more than the ionization energy of the K-shell electrons (*i.e.*, 72.5 keV). Therefore, characteristic X-ray spectrum will also be obtained because energy of incident electron is high enough to knock out the electron from K or L-shells.

52. (c) $\lambda_{k_\alpha} = 0.021\text{nm} = 0.21$Å

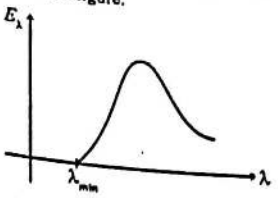
Since, λ_{k_α} corresponds to the transition of an electron from L-shell to K-shell, therefore

$E_L - E_K$ (in eV) $= \frac{12375}{\lambda(\text{in Å})}$

$= \frac{12375}{0.21} = 58928$ eV

or $\Delta E = 59$ keV

53. (b) The continuous X-ray spectrum is shown in figure.



All wavelengths $> \lambda_{min}$ are found, where

$\lambda_{min} = \frac{12375}{V(\text{in volt})}$ Å

Here, V is the applied voltage.

54. (b) Shortest wavelength or cut-off wavelength depends only upon the voltage applied in the coolidge tube.

55. (c)

56. (a,c) $\lambda_{min} = \frac{hc}{eV}$

$\Rightarrow \lambda_{min} \propto \frac{1}{V} \Rightarrow (\lambda_{min})_{new} = \frac{\lambda_2}{2}$

$\because I = \frac{dN}{dt} \times \frac{hc}{\lambda}$ $\because \frac{dN}{dt}$ decreases

Hence I decreases

57. (c, d) λ_m (in Å) $= \frac{12375}{V(\text{in volt})}$

With increase in V, λ_m will decrease. With decrease in λ_m energy of emitted photons will increase. And hence intensity will increase even if number of photons emitted per second are constant. Because intensity is basically energy per unit area per unit time.

58. λ_{min} (in Å) $= \frac{12375}{V\ (\text{in volts})}$

$\lambda_{min} = \frac{12375}{20\times10^3} = 0.62$Å

59. X-rays are electromagnetic waves and electromagnetic waves travel with the speed of light i.e. 3.0×10^8 m/s.

60. Ionization energy $E_1 \propto \left[\frac{1}{1^2} - \frac{1}{\infty}\right]$ ...(i)

and $E_1 = 40$ keV

Minimum energy to produce X-rays in the transition for $n = 2$ to $n = 1$ is,

$E_2 \propto \left[\frac{1}{1^2} - \frac{1}{2^2}\right]$ ...(ii)

From equations (i) and (ii), we get

$E_2 = \frac{3}{4} E_1 = 30$ keV

Therefore minimum voltage required is 30 keV or 30×10^3 V and the energy of characteristic radiation will be, 30 keV or 30×10^3 eV.

61. Cut-off wavelength is given by

$\lambda_{min} = \left\{\frac{12375}{V(\text{in volts})}\right\}$ (in Å)

with increase in applied voltage V, speed of electrons striking the anode is increased or cut-off wavelength of the emitted X-rays decreases.

Further, with increase in number of electrons striking the anode more number of photons of X-rays will be emitted.

Therefore, intensity of X-rays will increase.

62. (a) From the relation $r \propto A^{1/3}$,

We have, $\frac{r_2}{r_1} = \left(\frac{A_2}{A_1}\right)^{1/3}$ or $\left(\frac{A_2}{4}\right)^{1/3}$

$= (14)^{1/3}$

$\therefore A_2 = 56$

(b) $Z_2 = A_2 -$ number of neutrons

$= 56 - 30 = 26$

$\therefore f_{k_\alpha} = Rc(Z-1)^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

$= \frac{3Rc}{4}(Z-1)^2$

Substituting the given values of R, c and Z, we get

$f_{k_\alpha} = 1.55 \times 10^{18}$ Hz

63. $\Delta E = h\nu = Rhc\,(Z-b)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For K-series, $b = 1$

$\therefore \nu = Rc(Z-1)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

Substituting the values,

$4.2 \times 10^{18} = (1.1 \times 10^7)(3 \times 10^8)(Z-1)^2$

$\times \left(\frac{1}{1} - \frac{1}{4}\right)$

$\therefore (Z-1)^2 = 1697$

or $Z - 1 = 41$ or $Z = 42$

@RAJ_CBSE_X @RAJ_EDUNET

20 Nuclei

Scan for Sol.

JEE-Main

Properties of Nucleus

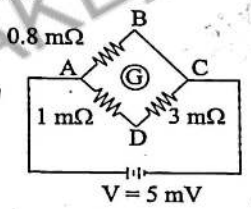
1. The electric potential at the surface of an atomic nucleus ($z = 50$) of radius 9×10^{-13} cm is $\times$ _____ 10^6 V. **[27 Jan, 2024 (Shift-II)]**

2. The mass number of nucleus having radius equal to half of the radius of nucleus with mass number 192 is: **[31 Jan, 2024 (Shift-II)]**
   (a) 24 (b) 32 (c) 40 (d) 20

3. A nucleus has mass number A_1 and volume V_1. Another nucleus has mass number A_2 and volume V_2. If relation between mass number is $A_2 = 4A_1$, then $\frac{V_2}{V_1} =$ _____. **[31 Jan, 2024 (Shift-II)]**

4. The radius of a nucleus of mass number 64 is 4.8 fermi. Then the mass number of another nucleus having radius of 4 fermi is $\frac{1000}{x}$, where x is _____. **[1 Feb, 2024 (Shift-I)]**

5. From the statements given below:
   (A) The angular momentum of an electron in nth orbit is an integral multiple of h.
   (B) Nuclear forces do not obey inverse square law.
   (C) Nuclear forces are spin dependent.
   (D) Nuclear forces are central and charge independent.
   (E) Stability of nucleus is inversely proportional to the value of packing fraction.



   Choose the correct answer from the options given below: **[1 Feb, 2024 (Shift-II)]**
   (a) (A), (B), (C), (D) only
   (b) (A), (C), (D), (E) only
   (c) (A), (B), (C), (E) only
   (d) (B), (C), (D), (E) only

6. A nucleus at rest disintegrates into two smaller nuclei with their masses in the ratio of 2:1. After disintegration they will move: **[09 April, 2024 (Shift-II)]**
   (a) In opposite directions with speed in the ratio of 1 : 2 respectively
   (b) In opposite directions with speed in the ratio of 2 : 1 respectively
   (c) In the same direction with same speed.
   (d) In opposite directions with the same speed.

7. Given below are two statements: One is labelled as **Assertion A** and the other is labelled as **Reason R.**
   Assertion A: The nuclear density of nuclides $^{10}_{5}B, ^{6}_{3}Li, ^{56}_{26}Fe, ^{20}_{10}Ne$ and $^{209}_{83}Bi$ can be arranged as $\rho^N_{Bi} > \rho^N_{Fe} > \rho^N_{Ne} > \rho^N_{B} > \rho^N_{Li}$.
   Reason R: The radius R of nucleus is related to its mass number A as $R = R_0 A^{1/3}$, where R_0 is a constant.
   In the light of the above statement, choose the correct answer from the options given below: **[30 Jan, 2023 (Shift-II)]**
   (a) Both A and R are true and R is the correct explanation of A
   (b) A is false but R is true
   (c) A is true but R is false
   (d) Both A and R are true but R is not the correct explanation of A

8. The ratio of the density of oxygen nucleus ($^{16}_{8}O$) and helium nucleus ($^{4}_{2}He$) is **[25 Jan, 2023 (Shift-I)]**
   (a) 4 : 1 (b) 8 : 1
   (c) 1 : 1 (d) 2 : 1

9. A nucleus disintegrates into two smaller parts, which have their velocities in the ratio 3 : 2. The ratio of their nuclear sizes will be $\left(\frac{x}{3}\right)^{\frac{1}{3}}$. The value of '$x$' is _____. **[25 Jan, 2023 (Shift-II)]**

10. Assume that protons and neutrons have equal masses. Mass of a nucleon is 1.6×10^{-7} kg and radius of nucleus is $1.5 \times 10^{-15} A^{1/3} m$. The approximate ratio of the nuclear density and water density is $n \times 10^{13}$. The value of n is _____ **[24 Jan, 2023 (Shift-I)]**

11. Read the following statements:
    (A) Volume of the nucleus is directly proportional to the mass number.
    (B) Volume of the nucleus is independent of mass number.
    (C) Density of the nucleus is directly proportional to the mass number.
    (D) Density of nucleus is directly proportional to the cube root of the mass number.
    (E) Density of the nucleus is independent of the mass number.
    Choose the correct option from the following options. **[29 July, 2022 (Shift-II)]**
    (a) (A) and (D) only. (b) (A) and (E) only.
    (c) (B) and (E) only. (d) (A) and (C) only.

@FAKE_JEE_X@FREE.NET

12. Mass numbers of two nuclei are in the ratio of 4 : 3. Their nuclear densities will be in the ratio of [26 July, 2022 (Shift-II)]

(a) 4 : 3 (b) $\left(\frac{3}{4}\right)^{\frac{1}{3}}$

(c) 1 : 1 (d) $\left(\frac{4}{3}\right)^{\frac{1}{3}}$

13. The radius R of a nucleus of mass number A can be estimated by the formula $R = (1.3 \times 10^{-15})A^{1/3}$ m. It follows that the mass density of a nucleus is of the order of: ($M_{prot} \approx M_{neut.} \approx 1.67 \times 10^{-27}$ kg) [3 Sep, 2020 (Shift-II)]

(a) 10^3 kg m^{-3} (b) 10^{17} kg m^{-3}

(c) 10^{10} kg m^{-3} (d) 10^{24} kg m^{-3}

14. The ratio of mass densities of nuclei of ^{40}Ca and ^{16}O is close to: [8 April, 2019 (Shift-II)]

(a) 1 (b) 2 (c) 0.1 (d) 5

Mass Defect and Binding Energy

15. Binding energy of a certain nucleus is 18×10^8 J. How much is the difference between total mass of all the nucleons and nuclear mass of the given nucleus: [08 April, 2024 (Shift-I)]

(a) 0.2 μg (b) 20 μg

(c) 2 μg (d) 10 μg

16. If Mo is the mass of isotope $^{12}_{5}B$, M_p and M_n are the masses of proton and neutron, then nuclear binding energy of isotope is: [08 April, 2024 (Shift-II)]

(a) $(5M_p + 7M_n - M_o)C^2$

(b) $(M_o - 5M_p)C^2$

(c) $(M_o - 12M_n)C^2$

(d) $(M_o - 5M_p - 7M_n)C^2$

17. For a nucleus ${}^{A}_{Z}X$ having mass number A and atomic number Z. [8 April, 2023 (Shift-I)]

(A) The surface energy per nucleon $(b_s) = a_1A^{2/3}$

(B) The Coulomb contribution to the binding energy $b_c = -a_2\frac{Z(Z-1)}{A^{4/3}}$

(C) The volume energy $b_v = a_3A$

(D) Decrease in the binding energy is proportional to surface area.

(E) While estimating the surface energy, it is assumed that each nucleon interacts with 12 nucleons, (a_1, a_2 and a_3 are constants)

Choose the most appropriate answer from the options given below:

(a) (C), (D) only (b) (B), (C), (E) only

(c) (A), (B), (C), (D) only (d) (B), (C) only

18. Given below are two statements: One is labelled as **Assertion A** and the other is labelled as **Reason R**

Assertion A: The binding energy per nucleon is practically independent of the atomic number for nuclei of mass number in the range 30 to 170.

Reason R: Nuclear force is short ranged.

In the light of the above statements, choose the correct answer from the options given below [13 April, 2023 (Shift-II)]

(a) Both A and R are true but R is not the correct explanation of A

(b) A is true but R is false

(c) A is false but R is true

(d) Both A and R are true and R is the correct explanation of A

19. The mass of proton, neutron and helium nucleus are respectively 1.0073 u, 1.0087 u and 4.0015 u. The binding energy of helium nucleus is: [01 Feb, 2023 (Shift-I)]

(a) 14.2 MeV (b) 28.4 MeV

(c) 56.8 MeV (d) 7.1 MeV

20. $^{238}_{92}A \rightarrow {}^{234}_{90}B + {}^{4}_{2}D + Q$

In the given nuclear reaction, the approximate amount of energy released will be:

[Given, mass of $^{238}_{92}A = 238.05079 \times 931.5$ MeV/c^2, mass of $^{234}_{90}B = 234.04363 \times 931.5$ MeV/c^2, mass of $^{4}_{2}D = 4.00260 \times 931.5$ MeV/c^2] [13 April, 2023 (Shift-I)]

(a) 3.82 MeV (b) 5.9 MeV

(c) 2.12 MeV (d) 4.25 MeV

21. Nucleus A having $Z = 17$ and equal number of protons and neutrons has 1.2*Me V* binding energy per nucleon. Another nucleus B of $Z = 12$ has total 26 nucleons and 1.8*Me V* binding energy per nucleons.

The difference of binding energy of B and A will be _____ *Me V*. [1 Feb, 2023 (Shift-II)]

22. Experimentally it is found that 12.8 eV energy is required to separate a hydrogen atom into a proton and an electron. So the orbital radius of the electron in a hydrogen atom is $\frac{9}{x} \times 10^{-10}$ m.

The value of the x is

(1eV = 1.6×10^{-19} J, $\frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ Nm^2/C^2 and electronic charge = 1.6×10^{-19} C) [6 April, 2023 (Shift-II)]

23. A nucleus with mass number 242 and binding energy per nucleon as 7.6 MeV breaks into fragment each with mass number 121. If each fragment nucleus has binding energy per nucleon as 8.1 MeV, the total gain in binding energy is _____ MeV [8 April, 2023 (Shift-I)]

24. Nucleus A is having mass number 220 and its binding energy per nucleon is 5.6 MeV. It splits in two fragments '*B*' and '*C*' of mass numbers 105 and 115. The binding energy of nucleons in '*B*' and '*C*' 6.4 MeV per nucleon. The energy Q released per fission will be: [24 June, 2022 (Shift-I)]

(a) 0.8 MeV (b) 275 MeV (c) 220 MeV (d) 176 MeV

25. The Q-value of a nuclear reaction and kinetic energy of the projectile particle, K_p are related as: [28 June, 2022 (Shift-I)]

(a) $Q = K_p$ (b) $(K_p + Q) < 0$

(c) $Q < K_p$ (d) $(K_p + Q) > 0$

26. Two lighter nuclei combine to form a comparatively heavier nucleus by the relation given below:

$^{2}_{1}X + {}^{2}_{1}X = {}^{4}_{2}Y$

The binding energies per nucleon for $^{2}_{1}X$ and $^{4}_{2}Y$ are 1.1 MeV and 7.6 MeV respectively. The energy released in this process is____MeV. [26 July, 2022 (Shift-II)]

@FAKE_CBSE_X @RAJ_EDUNET

27. The minimum kinetic energy needed by an alpha particle to cause the nuclear reaction $^{16}_{7}N + {}^{4}_{2}He \rightarrow {}^{1}_{1}H + {}^{19}_{8}O$ in a laboratory frame is n (in MeV). Assume that $^{16}_{7}N$ is at rest in the laboratory frame. The masses of $^{16}_{7}N$, $^{4}_{2}He$, $^{1}_{1}H$ and $^{19}_{8}O$ can be taken to be 16.006 u, 4.003 u, 1.008 u and 19.003 u, respectively, where 1 u = 930 MeVc^{-2}. The value of n is_____. **[JEE Adv, 2022]**

28. The binding energy of nucleons in a nucleus can be affected by the pairwise Coulomb repulsion. Assume that all nucleons are uniformly distributed inside the nucleus. Let the binding energy of a proton be E_b^p and the binding energy of a neutron be E_b^n in the nucleus. **[JEE Adv, 2022]**
Which of the following statement(s) is(are) correct?
(a) $E_b^p - E_b^n$ is proportional to $Z(Z-1)$ where Z is the atomic number of the nucleus.
(b) $E_b^p - E_b^n$ is proportional to $A^{-\frac{1}{3}}$ where A is the mass number of the nucleus.
(c) $E_b^p - E_b^n$ is positive.
(d) E_b^p increases if the nucleus undergoes a beta decay emitting a positron.

29. From the given data, the amount of energy required to break the nucleus of aluminium $^{27}_{13}Al$ is _____ $x \times 10^{-3}$ J.
[25 July, 2021 (Shift-II)]
Mass of neutron = 1.00866u
Mass of proton = 1.00726 u
Mass of Aluminium nucleus = 27.18846 u
(Assume 1 u corresponds to x J of energy)
(Round off to the nearest integer)

30. A heavy nucleus N, at rest, undergoes fission $N \rightarrow P + Q$, where P and Q are two lighter nuclei. Let $\delta = M_N - M_P - M_Q$, where M_P, M_Q and M_N are the masses of P, Q and N, respectively. E_P and E_Q are the kinetic energies of P and Q, respectively. The speed of P and Q are v_P and v_Q, respectively. If c is the speed of light, which of the following statement(s) is (are) correct? **[JEE Adv, 2021]**
(a) $E_P + E_Q = c^2\delta$
(b) $E_P = \left(\frac{M_P}{M_P + M_Q}\right)c^2\delta$
(c) $\frac{v_P}{v_Q} = \frac{M_Q}{M_P}$
(d) The magnitude of momentum for P as well as Q is $c\sqrt{2\mu\delta}$, where $\mu = \frac{M_P M_Q}{(M_P + M_Q)}$

31. You are given that Mass of $^{7}_{3}Li = 7.0160u$ Mass of $^{4}_{2}He = 4.0026u$ and $^{1}_{1}H = 1.0079u$. When 20 g of $^{7}_{3}Li$ is converted into $^{4}_{2}He$ by proton capture, the energy liberated, (in kWh), is [Mass of nucleon $= \frac{1Gev}{c^2}$] **[2020]**
(a) 4.5×10^5
(b) 8×10^6
(c) 6.82×10^5
(d) 1.33×10^6

32. Given the masses of various atomic particles $m_p = 1.0072$ u, $m_n = 1.0087$ u, $m_e = 0.000548$ u, $m_{\bar{\nu}} = 0$, $m_d = 2.0141$ u, where p ≡ proton, n ≡ neutron, e ≡ electron, $\bar{\nu}$ ≡ antineutrino and d ≡ deuteron. Which of the following process is allowed by momentum and energy conservation? **[6 Sep, 2022 (Shift-II)]**
(a) $n + n \rightarrow$ deuterium atom (electron bound to the nucleus)
(b) $n + p \rightarrow d + \gamma$
(c) $p \rightarrow n + e^+ + \bar{\nu}$
(d) $e^+ + e^- \rightarrow \gamma$

33. Find the binding energy per nucleon for $^{120}_{50}Sn$. Mass of proton $m_p = 1.00783$ u, mass of neutron $m_n = 1.00867$ u and mass of tin nucleus $m_{Sn} = 119.902199$ u.
(Take 1 u = 931 MeV) **[4 Sep, 2020 (Shift-II)]**
(a) 9.0 MeV (b) 8.5 MeV
(c) 8.0 MeV (d) 7.5 MeV

34. In a reactor, 2 kg of $_{92}U^{235}$ fuel is fully used up in 30 days. The energy released per fission is 200 MeV. Given that the Avogadro number, $N = 6.023 \times 10^{26}$ per kilo mole and 1 $eV = 1.6 \times 10^{-19}$ J. The power output of the reactor is close to **[2 Sep, 2020 (Shift-I)]**
(a) 125 MW (b) 35 MW
(c) 60 MW (d) 54 MW

35. Consider the nuclear fission $Ne^{20} \rightarrow 2He^4 + C^{12}$. Given that the binding energy / nucleon of Ne^{20}, He^4 and C^{12} are, respectively, 8.03 MeV, 7.07 MeV, and 7.86 MeV, identify the correct statement: **[10 Jan, 2019 (Shift-II)]**
(a) energy of 12.4 MeV will be supplied
(b) 8.3 MeV energy will be released
(c) energy of 3.6 MeV will be released
(d) energy of 11.9 MeV has to be supplied

Mass Energy Relation, B.E, Fission & Fusion

36. In a nuclear fission process, a high mass nuclide (A ≈ 236) with binding energy 7.6 MeV/Nucleon dissociated into middle mass nuclides (A ≈ 118), having binding energy of 8.6 MeV/Nucleon. The energy released in the process would be _____ MeV.
[27 Jan, 2024 (Shift-I)]

37. The atomic mass of $_6C^{12}$ is 12.000000u and that of $_6C^{13}$ is 13.003354u. The required energy to remove a neutron from $_6C^{13}$, if mass of neutron is 1.008665u, will be: **[27 JAN, 2024 (Shift-II)]**
(a) 62.5 MeV (b) 6.25 MeV
(c) 4.95 MeV (d) 49.5 MeV

38. The explosive in a Hydrogen bomb is a mixture of $_1H^2$, $_1H^3$ and $_3Li^6$ in some condensed form. The chain reaction is given by
[29 Jan, 2024 (Shift-I)]
$_3Li^6 + {}_0n^1 \rightarrow {}_2He^4 + {}_1H^3$
$_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + {}_0n^1$
During the explosion the energy released is approximately
[Given: M(Li) = 6.01690 amu. M ($_1H^2$) = 2.01471 amu. M ($_2He^4$) = 4.00388amu, and 1 amu = 931.5 MeV]
(a) 28.12 MeV (b) 12.64 MeV
(c) 16.48 MeV (d) 22.22 MeV

@FAKE_CBSE_@RAJEDUNET

39. In a nuclear fission reaction of an isotope of mass M, three similar daughter nuclei of same mass are formed. The speed of a daughter nuclei in terms of mass defect ΔM will be: [30 Jan, 2024 (Shift-II)]

(a) $\sqrt{\frac{2c\Delta M}{M}}$ (b) $\sqrt{\frac{\Delta Mc^2}{3}}$

(c) $c\sqrt{\frac{2\Delta M}{M}}$ (d) $c\sqrt{\frac{3\Delta M}{M}}$

40. The mass defect in a particular reaction is 0.4g. The amount of energy liberated is $n \times 10^7$ kWh, where $n =$ _____.
(speed of light $= 3 \times 10^8$ m/s) [31 Jan, 2024 (Shift-I)]

41. Which of the following nuclear fragments corresponding to nuclear fission between neutron $\left({}_0^1n\right)$ and uranium isotope $\left({}_{92}^{235}U\right)$ is correct: [04 April, 2024 (Shift-I)]

(a) ${}_{56}^{144}Ba + {}_{36}^{89}Kr + 4{}_0^1n$ (b) ${}_{56}^{140}Xe + {}_{38}^{94}Sr + 3{}_0^1n$

(c) ${}_{51}^{153}Sb + {}_{41}^{99}Nb + 3{}_0^1n$ (d) ${}_{56}^{144}Ba + {}_{36}^{89}Kr + 3{}_0^1n$

42. The disintegration energy Q for the nuclear fission of ${}^{235}U \rightarrow {}^{140}Ce + {}^{94}Zr + n$ is _____ MeV. [04 April, 2024 (Shift-II)]
Given atomic masses of
${}^{235}U$: 235.0439u; ${}^{140}Ce$: 139.9054u,
${}^{94}Zr$: 93.9063u; n : 1.0086u,
Value of $c^2 = 931$ MeV/u.

43. If three helium nuclei combine to form a carbon nucleus then the energy released in this reaction is ..... $\times 10^{-2}$ MeV. (Given 1 u = 931 MeV/c^2, atomic mass of helium = 4.002603 u) [05 April, 2024 (Shift-I)]

44. In a hypothetical fission reaction

${}_{92}X^{236} \rightarrow {}_{56}Y^{141} + {}_{36}Z^{92} + 3R$

The identity of emitted particles (R) is: [08 April, 2024 (Shift-II)]
(a) Proton (b) Electron
(c) Neutron (d) γ-radiations

45. The energy equivalent of 1g of substance is: [09 April, 2024 (Shift-I)]
(a) 11.2×10^{24} MeV (b) 5.6×10^{12} MeV
(c) 5.6 eV (d) 5.6×10^{26} MeV

46. A star has 100% helium composition. It starts to convert three 4He into one ${}^{12}C$ via triple alpha process as ${}^4He + {}^4He + {}^4He \rightarrow {}^{12}C + Q$. The mass of the star is 2.0×10^{32} kg and it generates energy at the rate of 5.808×10^{30} W. The rate of converting these ${}^4He$ to ${}^{12}C$ is $n \times 10^{42}$ s^{-1}, where n is _____. [09 April, 2024 (Shift-I)]

47. The energy released in the fusion of 2 kg of hydrogen deep in the sun is E_H and the energy released in the fission of 2 kg of ${}^{235}U$ is E_U. The ratio E_H/E_U is approximately:
(Consider the fusion reaction as
$4{}_1^1H + 2e^- \rightarrow {}_2^4He + 2\nu + 6\gamma + 26.7$ MeV, energy released in the fission reaction of ${}^{235}U$ is 200 MeV per fission nucleus and $N_A = 6.023 \times 10^{23}$) [09 April, 2024 (Shift-II)]
(a) 9.13 (b) 15.04 (c) 7.62 (d) 25.6

48. A free neutron decays into a proton but a free proton does not decay into neutron. This is because [31 Jan, 2023 (Shift-I)]
(a) neutron is an uncharged particle
(b) proton is a charged particle
(c) neutron is a composite particle made of a proton and an electron
(d) neutron has larger rest mass than proton

49. Consider the following statements: [27 July, 2021 (Shift-II)]
(A) Atoms of each element emit characteristics spectrum.
(B) According to Bohr's Postulate, an electron in a hydrogen atom, revolves in a certain stationary orbit.
(C) The density of nuclear matter depends on the size of the nucleus.
(D) A free neutron is stable but a free proton decay is possible.
(E) Radioactivity is an indication of the instability of nuclei.
Choose the correct answer from the options given below:
(a) (B) and (D) only
(b) (A), (C) and (E) only
(c) (A), (B), (C), (D) and (E)
(d) (A), (B) and (E) only

50. The decay of a proton to neutron is: [18 March, 2021 (Shift-II)]
(a) Possible only inside the nucleus
(b) Not possible but neutron to proton conversion is possible
(c) Not possible as proton mass is less than the neutron mass
(d) Always possible as it is associated only with β^+ decay

51. The energy released per fission of nucleus of ${}^{240}X$ is 200 MeV. The energy released if all the atoms in 120 g of pure ${}^{240}X$ undergo fission is _____ $\times 10^{25}$ MeV.
(Given $N_A = 6 \times 10^{23}$) [24 Jan, 2023 (Shift-II)]

52. A nucleus of mass M emits γ-ray photon of frequency '$h\nu$'. The loss of internal energy by the nucleus is: [Take 'c' as the speed of electromagnetic wave] [20 July, 2021 (Shift-I)]

(a) $h\nu\left[1+\frac{h\nu}{2Mc^2}\right]$ (b) 0

(c) $h\nu\left[1-\frac{h\nu}{2Mc^2}\right]$ (d) $h\nu$

@MKE_CBSE_X@DM_EDUPET

Properties of Nucleus

Single Correct

1. Order of magnitude of density of uranium nucleus is ($m_p = 1.67 \times 10^{-27}$ kg) **(IIT-JEE 1999)**

(a) 10^{20} kg/m^3 (b) 10^{17} kg/m^3

(c) 10^{14} kg/m^3 (d) 10^{11} kg/m^3

Numerical Types/Integer Types

2. When radiation of wavelength λ is used to illuminate a metallic surface, the stopping potential is V. When the same surface is illuminated with radiation of wavelength 3λ, the stopping potential is $\frac{V}{4}$. If the threshold wavelength for the metallic surface is $n\lambda$ then value of n will be **(JEE Adv. 2021)**

Mass Defect and Binding Energy

Single Correct

3. The electrostatic energy of Z protons uniformly distributed throughout a spherical nucleus of radius R is given by

$$E = \frac{3}{5}\frac{Z(Z-1)e^2}{4\pi\varepsilon_0 R}$$

The measured masses of the particles neutron, $^1_1$H, $^{15}_7$N and $^{15}_8$O are 1.008665 u, 1.007825 u, 15.000109 u and 15.003065 u, respectively. Given that the radii of both the $^{15}_7$N and $^{15}_8$O nuclei are same, 1 u = 931.5 MeV/c^2 (c is the speed of light) and $e^2/(4\pi\varepsilon_0)$ = 1.44 MeV fm. Assuming that the difference between the binding energies of $^{15}_7$N and $^{15}_8$O is purely due to the electrostatic energy, the radius of either of the nuclei is (1 fm = 10^{-15} m)

C-13.62 W-24.77 UA-61.61 (JEE Adv. 2016)

(a) 2.85 fm (b) 3.03 fm (c) 3.42 fm (d) 3.80 fm

4. In the options given below, let E denote the rest mass energy of a nucleus and n a neutron. The correct option is **(IIT-JEE 2007)**

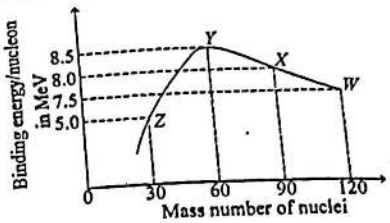
(a) $E(^{236}_{92}\text{U}) > E(^{137}_{53}\text{I}) + E(^{97}_{39}\text{Y}) + 2E(n)$

(b) $E(^{236}_{92}\text{U}) < E(^{137}_{53}\text{I}) + E(^{97}_{39}\text{Y}) + 2E(n)$

(c) $E(^{236}_{92}\text{U}) < E(^{140}_{56}\text{Ba}) + E(^{94}_{36}\text{Kr}) + 2E(n)$

(d) $E(^{235}_{92}\text{U}) < E(^{140}_{56}\text{Ba}) + E(^{94}_{36}\text{Kr}) + E(n)$

5. Binding energy per nucleon versus mass number curve for nuclei is shown in figure. W, X, Y and Z are four nuclei indicated on the curve. The process that would release energy is **(IIT-JEE 1999)**



(a) $Y \to 2Z$ (b) $W \to X + Z$ (c) $W \to 2Y$ (d) $X \to Y + Z$

Multiple Correct

6. The binding energy of nucleons in a nucleus can be affected by the pairwise Coulomb repulsion. Assume that all nucleons are uniformly distributed inside the nucleus. Let the binding energy of a proton be E_b^p and the binding energy of a neutron be E_b^n in the nucleus.

Which of the following statement(s) is/are correct?

C-1.38 W-21.74 UA-55.94 (JEE Adv. 2022)

(a) $E_b^p - E_b^n$ is proportional to $Z(Z-1)$ where Z is the atomic number of the nucleus.

(b) $E_b^p - E_b^n$ is proportional to $A^{-\frac{1}{3}}$ where A is the mass number of the nucleus.

(c) $E_b^p - E_b^n$ is positive.

(d) E_b^p increases if the nucleus undergoes a beta decay emitting a positron.

7. A heavy nucleus N, at rest, undergoes fission $N \to P + Q$, where P and Q are two lighter nuclei. Let $\delta = M_N - M_P - M_Q$, where M_P, M_Q and M_N are the masses of P, Q and N, respectively. E_P and E_Q are the kinetic energies of P and Q, respectively. The speed of P and Q are v_P and v_Q, respectively. If c is the speed of light, which of the following statement(s) is/are correct?

C-10.92 W-23.16 UA-38.09 PC-27.84 (JEE Adv. 2021)

(a) $E_P + E_Q = c^2\delta$

(b) $E_P = \left(\frac{M_P}{M_P + M_Q}\right)c^2\delta$

(c) $\frac{v_P}{v_Q} = \frac{M_Q}{M_P}$

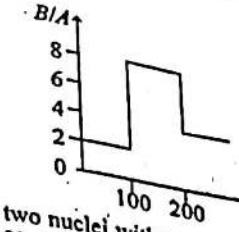
(d) The magnitude of momentum for P as well as Q is $c\sqrt{2\mu\delta}$, where $\mu = \frac{M_P M_Q}{(M_P + M_Q)}$

8. Assume that the nuclear binding energy per nucleon (B/A) versus mass number (A) is as shown in the figure.

Use this plot to choose the correct choice(s) given below.

(IIT-JEE 2008)

@FAKE_CBSE_X @RAJ_EDUNET



(a) Fusion of two nuclei with mass numbers lying in the range of $1 < A < 50$ will release energy.

(b) Fusion of two nuclei with mass numbers lying in the range of $51 < A < 100$ will release energy.

(c) Fission of a nucleus lying in the mass range of $100 < A < 200$ will release energy when broken into two equal fragments.

(d) Fission of a nucleus lying in the mass range of $200 < A < 260$ will release energy when broken into two equal fragments.

9. Let m_p be the mass of proton, m_n the mass of neutron. M_1 the mass of $^{20}_{10}Ne$ nucleus and M_2 the mass of $^{20}_{40}Ca$ nucleus. Then

(a) $M_2 = 2M_1$ (b) $M_2 > 2M_1$ (IIT-JEE 1998)

(c) $M_2 < 2M_1$ (d) $M_1 < 10(m_n + m_p)$

Comprehension Based/Passage Based

Passage 1

The mass of a nucleus $^{A}_{Z}X$ is less than the sum of the masses of $(A - Z)$ number of neutrons and Z number of protons in the nucleus. The energy equivalent to the corresponding mass difference is known as the binding energy of the nucleus. A heavy nucleus of mass M can break into two light nuclei of masses m_1 and m_2 only if $(m_1 + m_2) < M$. Also two light nuclei of masses m_3 and m_4 can undergo complete fusion and form a heavy nucleus of mass M' only if $(m_3 + m_4) M'$. The masses of some neutral atoms are given in the table below

$^{1}_{1}H$	1.007825u	$^{2}_{1}H$	2.014102u
$^{6}_{3}Li$	6.01513u	$^{7}_{3}Li$	7.016004u
$^{152}_{64}Gd$	151.919803u	$^{206}_{82}Pb$	205.974455u
$^{3}_{1}H$	3.016050u	$^{4}_{2}He$	4.002603u
$^{70}_{30}Zn$	69.925325u	$^{82}_{34}Se$	81.916709u

10. The correct statement is

C-41.67 W-36.09 UA-22.24 (JEE Adv. 2013)

(a) The nucleus $^{6}_{3}Li$ can emit an alpha particle.

(b) The nucleus $^{210}_{84}PO$ can emit a proton.

(c) Deuteron and alpha particle can undergo complete fusion.

(d) The nuclei $^{70}_{30}Zn$ and $^{34}_{82}Se$ can undergo complete fusion.

11. The kinetic energy (in keV) of the alpha particle, when the nucleus $^{210}_{84}Po$ at rest undergoes alpha decay, is

C-10.16 W-42.02 UA-47.82 (JEE Adv. 2013)

(a) 5316 (b) 5422 (c) 5707 (d) 5818

Passage 2

The β-decay process, discovered around 1900, is basically the decay of a neutron (n). In the laboratory, a proton (p) and an electron (e^-) are observed as the decay products of the neutron. Therefore, considering the decay of a neutron as a two-body decay process, it was predicted theoretically that the kinetic energy of the electron should be a constant. But experimentally, it was observed that the electron kinetic energy has a continuous spectrum. Considering a three-body decay process, i.e., $n \rightarrow p + e^- + \bar{\nu}_e$, around 1930, Pauli explained the observed electron energy spectrum.

Assuming the anti-neutrino ($\bar{\nu}_e$) to be massless and possessing negligible energy, and the neutron to be at rest, momentum and energy conservation principles are applied. From this calculation, the maximum kinetic energy of the electron is 0.8×10^6 eV. The kinetic energy carried by the proton is only the recoil energy.

12. If the anti-neutrino had a mass of 3 eV/c^2 (where c is the speed of light) instead of zero mass, what should be the range of the kinetic energy K, of the electron?

C-12.44 W-54.32 UA-33.24 (IIT-JEE 2012)

(a) $0 \le K \le 0.8 \times 10^6$ eV (b) $3.0 \text{ eV} \le K \le 0.8 \times 10^6$ eV

(c) $3.0 \text{ eV} \le K < 0.8 \times 10^6$ eV (d) $0 \le K < 0.8 \times 10^6$ eV

13. What is the maximum energy of the anti-neutrino?

C-19.09 W-58.87 UA-22.04 (IIT-JEE 2012)

(a) Zero

(b) Much less than 0.8×10^6 eV

(c) Nearly 0.8×10^6 eV

(d) Much larger than 0.8×10^6 eV

Match the Column

14. Four physical quantities are listed in Column-I. Their values are listed in Column-II in a random order (IIT-JEE 1987)

	Column-I		Column-II
A.	Thermal energy of air molecules at room temperature.	(i)	0.02 eV
B.	Binding energy of heavy nuclei per nucleon.	(ii)	2 eV
C.	X-ray photon energy.	(iii)	10 keV
D.	Photon energy of visible light.	(iv)	7 MeV

The correct matching of Columns-I and II is given by :

	A	B	C	D
(a)	i	iv	iii	ii
(b)	i	iii	ii	iv
(c)	ii	i	iii	iv
(d)	ii	iv	i	iii

Numerical Types/Integer Types

15. The minimum kinetic energy needed by an alpha particle to cause the nuclear reaction $^{16}_{7}N + ^{4}_{2}He \rightarrow ^{1}_{1}H + ^{19}_{8}O$ in a laboratory frame is n (in MeV). Assume that $^{16}_{7}N$ is at rest in the laboratory frame. The masses of $^{16}_{7}N$, $^{4}_{2}He$, $^{1}_{1}H$ and $^{19}_{8}O$ can be taken to be 16.006 u, 4.003 u, 1.008 u and 19.003 u, respectively, where 1 u = 930 MeVc^{-2}. The value of n is_____.

C-0.81 W-67.38 UA-31.81 (JEE Adv. 2022)

Fill in the Blanks

16. The binding energies per nucleon for deuteron ($_1H^2$) and helium ($_2He^4$) are 1.1 MeV and 7.0 MeV respectively. The energy released when two deuterons fuse to form a helium nucleus ($_2He^4$) is ..... .

(IIT-JEE 1988)

@FAKE-CBSE-KOTA-EDUNET

Subjective

17. A radioactive nucleus X decays to a nucleus Y with a decay constant $\lambda_x = 0.1s^{-1}$, Y further decays to a stable nucleus Z with a decay constant $\lambda_y = 1/30s^{-1}$. Initially, there are only X nuclei and their number is $N_0 = 10^{20}$. Set-up the rate equations for the populations of X, Y and Z. The population of Y nucleus as a function of time is given by $N_y(t) = \{N_0\lambda_x/(\lambda_x - \lambda_y)\}[exp(-\lambda_y t) - exp(-\lambda_x t)]$. Find the time at which N_y is maximum and determine the populations X and Z at that instant. **(IIT-JEE 2001)**

18. It is proposed to use the nuclear fusion reaction;
$^2_1H + {}^2_1H \rightarrow {}^4_2He$
in a nuclear reactor of 200MW rating. If the energy from the above reaction is used with a 25 per cent efficiency in the reactor, how many grams of deuterium fuel will be needed per day? (The masses of ^2_1H and ^4_2He are 2.0141 atomic mass units and 4.0026 atomic mass units respectively. **(IIT-JEE 1990)**

Radioactive Decay and Statistical Law of Radioactive Decay

Single Correct

19. A heavy nucleus Q of half-life 20 minutes undergoes alpha-decay with probability of 60% and beta-decay with probability of 40%. Initially, the number of Q nuclei is 1000. The number of alpha decays of Q in the first one hour is

C-30.94 W-31.04 UA-38.02 (JEE Adv. 2021)

(a) 50 (b) 75 (c) 350 (d) 525

20. In a radioactive sample, $^{40}_{19}K$ nuclei either decay into stable $^{40}_{20}Ca$ nuclei with decay constant 4.5×10^{-10} per year or into stable $^{40}_{18}Ar$ nuclei with decay constant 0.5×10^{-10} per year. Given that in this sample all the stable $^{40}_{20}Ca$ and $^{40}_{18}Ar$ nuclei are produced by the $^{40}_{19}K$ nuclei only. In time $t \times 10^9$ years. if the ratio of the sum of stable $^{40}_{20}Ca$ and $^{40}_{18}Ar$ nuclei to the radioactive $^{40}_{19}K$ nuclei is 99, the value of t will be: [Given In 10 = 2.3]

C-17 W-32 UA-51 (JEE Adv. 2019)

(a) 9.2 (b) 1.15 (c) 4.6 (d) 2.3

21. A radioactive nucleus A with a half-life T, decays into a nucleus B. At $t = 0$, there is no nucleus B. After sometime t, the ratio of the number of B to that of A is 0.3. Then, t is given by

(JEE Adv. 2017)

(a) $t = \frac{\log 1.3}{\log 2}T$ (b) $t = T\log 1.3$

(c) $t = \frac{T}{\log 1.3}$ (d) $t = \frac{T\log 2}{\log 1.3}$

22. An accident in a nuclear laboratory resulted in deposition of a certain amount of radioactive material of half-life 18 days inside the laboratory. Tests revealed that the radiation was 64 times more than the permissible level required for safe operation of the laboratory. What is the minimum number of days after which the laboratory can be considered safe for use?

C-61.37 W-20.28 UA-18.35 (JEE Adv. 2016)

(a) 64 (b) 90 (c) 108 (d) 120

23. A fission reaction is given by $^{236}_{92}U \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr + x + y$, where x and y are two particles. Considering $^{236}_{92}U$ to be at rest, the kinetic energies of the products are denoted by K_{Xe}, K_{Sr}, K_x(2 MeV) and K_y(2 MeV), respectively. Let the binding energies per nucleon of $^{236}_{92}U$, $^{140}_{54}Xe$ and $^{94}_{38}Sr$ be 7.5 MeV, 8.5 MeV and 8.5 MeV, respectively. Considering different conservation laws, the correct options is/are **(JEE Adv. 2015)**

(a) $x = n, y = n, K_{Sr} = 129MeV, K_{Xe} = 86MeV$

(b) $x = p, y = e^-, K_{Sr} = 129MeV, K_{Xe} = 86MeV$

(c) $x = p, y = n, K_{Sr} = 129MeV, K_{Xe} = 86MeV$

(d) $x = n, y = n, K_{Sr} = 86MeV, K_{Xe} = 129MeV$

24. A radioactive sample S_1 having an activity of $5\mu Ci$ has twice the number of nuclei as another sample S_2 which has an activity of $10\mu Ci$. The half lives of S_1 and S_2 can be **(IIT-JEE 2008)**

(a) 20yr and 5yr, respectively (b) 20yr and 10yr, respectively

(c) 10yr each (d) 5yr each

25. After 280 days, the activity of a radioactive sample is $6000dps$. The activity reduces to $3000dps$ after another 140 days. The initial activity of the sample in dps is **(IIT-JEE 2004)**

(a) 6000 (b) 9000 (c) 3000 (d) 24000

26. Which of the following processes represent a γ-decay?

(IIT-JEE 2002)

(a) $^AX_Z + \gamma \rightarrow {}^AX_{Z-1} + a + b$ (b) $^AX_Z + {}^1n_0 \rightarrow {}^{A-3}X_{Z-2} + c$

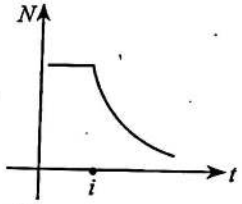
(c) $^AX_Z \rightarrow {}^AX_Z + f$ (d) $^AZ + e_{-1} \rightarrow {}^AX_{A-1} + g$

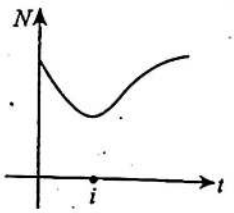
27. The half-life of ^{215}At is $100\mu s$. The time taken for the activity of a sample of ^{215}At to decay to $\frac{1}{16}$ th of its initial value is

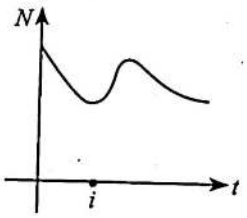
(IIT-JEE 2002)

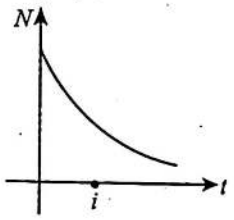
(a) $400\mu s$ (b) $63\mu s$ (c) $40\mu s$ (d) $300\mu s$

28. A radioactive sample consists of two distinct species having equal number of atoms initially. The mean life of one species is τ and that of the other is 5τ. The decay products in both cases are stable. A plot is made of the total number of radioactive nuclei as a function of time. Which of the following figure best represents the form of this plot ? **(IIT-JEE 2001)**

(a) 

(b) 

(c) 

(d) 

29. The electron emitted in beta radiation originates from

(IIT-JEE 2001)

(a) Inner orbits of atom

(b) Free electrons existing in nuclei

(c) Decay of a neutron in a nucleus

(d) Photon escaping from the nucleus

@NKE_CBSE_X@RAJ_EDUNET

30. Two radioactive materials X_1 and X_2 have decay constants 10λ and λ respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of X_1 to that of X_2 will be $1/e$ after a time (IIT-JEE 2000)

(a) $1/10\lambda$ (b) $1/11\lambda$ (c) $11/10\lambda$ (d) $1/9\lambda$

31. The half-life period of a radioactive element x is same as the mean life time of another radioactive element y. Initially both of them have the same number of atoms. Then (IIT-JEE 1999)

(a) x and y have the same decay rate initially

(b) x and y decay at the same rate always

(c) y will decay at a faster rate than x

(d) x will decay at a faster rate than y

32. ^{22}Ne nucleus, after absorbing energy, decays into two a-particles and an unknown nucleus. The unknown nucleus is (IIT-JEE 1999)

(a) nitrogen (b) carbon (c) boron (d) oxygen

33. The half-life of ^{131}I is 8 days. Given a sample of ^{131}I at time $t = 0$, we can assert that (IIT-JEE 1998)

(a) no nucleus will decay before $t = 4$ days

(b) no nucleus will decay before $t = 8$ days

(c) all nuclei will decay before $t = 16$ days

(d) a given nucleus may decay at any time after $t = 0$

34. Consider α-particles, β-particles and γ-rays each having an energy of 0.5 MeV. In increasing order of penetrating powers, the radiations are (IIT-JEE 1994)

(a) α, β, γ (b) α, γ, β (c) β, γ, α (d) γ, β, α

35. A freshly prepared radioactive source of half-life 2 h emits radiation of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with this source is (IIT-JEE 1988)

(a) 6 h (b) 12 h (c) 24 h (d) 128 h

36. The decay constant of a radioactive sample is λ. The half-life and mean-life of the sample are respectively given by (IIT-JEE 1989)

(a) $1/\lambda$ and $(\ln 2)/\lambda$ (b) $(\ln 2)/\lambda$ and $1/\lambda$

(c) $\lambda (\ln 2)$ and $1/\lambda$ (d) $\lambda/(\ln 2)$ and $1/\lambda$

37. During a negative beta decay, (IIT-JEE 1987)

(a) an atomic electron is ejected

(b) an electron which is already present within the nucleus is ejected

(c) a neutron in the nucleus decays emitting an electron

(d) a part of the binding energy of the nucleus is converted into an electron

38. During a nuclear fusion reaction (IIT-JEE 1987)

(a) a heavy nucleus breaks into two fragments by itself

(b) a light nucleus bombarded by thermal neutrons breaks up

(c) a heavy nucleus bombarded by thermal neutrons breaks up

(d) two light nuclei combine to give a heavier nucleus and possibly other products

39. The half-life of the radioactive radon is 3.8 days. The time, at the end of which 1/20th of the radon sample will remain undecayed, is (given $\log_{10} e = 0.4343$) (IIT-JEE 1981)

(a) 3.8 days (b) 16.5 days (c) 33 days (d) 76 days

Multiple Correct

40. In a radioactive decay chain, $^{232}_{90}Th$ nucleus decays to $^{212}_{82}Pb$ nucleus. Let N_α and N_β be the number of α and β- particles respectively, emitted in this decay process. Which of the following statements is/are true?

C-57.4, W-24.25, UA-12.35, PC-6.01 (JEE Adv. 2018)

(a) $N_\alpha = 5$ (b) $N_\alpha = 6$ (c) $N_\beta = 2$ (d) $N_\beta = 4$

41. From the following equations pick out the possible nuclear fusion reactions (IIT-JEE 1984)

(a) $_6C^{13} + {}_1H^1 \longrightarrow {}_6C^{14} + 4.3$ MeV

(b) $_6C^{12} + {}_1H^1 \longrightarrow {}_7N^{13} + 2$ MeV

(c) $_7N^{14} + {}_1H^1 \longrightarrow {}_8C^{15} + 7.3$ MeV

(d) $_{92}U^{235} + {}_0n^1 \longrightarrow {}_{54}Xe^{140} + 36Sr^{94} + {}_0n^1 + {}_0n^1 + \gamma + 200$ MeV

Comprehension Based/Passage Based

Passage 1

Scientists are working hard to develop nuclear fusion reactor. Nuclei of heavy hydrogen, ^2_1H known as deuteron and denoted by D can be thought of as a candidate for fusion reactor. The D-D reaction is $^2_1H + {}^2_1H \rightarrow {}^3_2He + n +$ energy. In the core of fusion reactor, a gas of heavy hydrogen is fully ionized into deuteron nuclei and electrons. This collection of ^2_1H nuclei and electrons is known as plasma. The nuclei move randomly in the reactor core and occasionally come close enough for nuclear fusion to take place.

Usually, the temperatures in the reactor core are too high and no material wall can be used to confine the plasma. Special techniques are used which confine the plasma for a time t_0 before the particles fly away from the core. If n is the density (number/volume) of deuterons, the product nt_0 is called Lawson number. In one of the criteria, a reactor is termed successful if Lawson number is greater than 5×10^{14} s cm^{-3}.

It may be helpful to use the following : Boltzmann constant

$k = 8.6 \times 10^{-5}$ eV/K; $\frac{e^2}{4\pi\varepsilon_0}$ eVm $= 1.44 \times 10^{-9}$ eVm.

42. In the core of nuclear fusion reactor, the gas becomes plasma because of (IIT-JEE 2009)

(a) strong nuclear force acting between the deuterons.

(b) Coulomb force acting between the deuterons.

(c) Coulomb force acting between deuteron-electron pairs.

(d) the high temperature maintained inside the reactor core.

43. Assume that two deuteron nuclei in the core of fusion reactor at temperature T are moving towards each other, each with kinetic energy 1.5 kT, when the separation between them is large enough to neglect Coulomb potential energy. Also neglect any interaction from other particles in the core. The minimum temperature T required for them to reach a separation of 4×10^{-15} m is in the range (IIT-JEE 2009)

(a) 1.0×10^9 K $< T < 2.0 \times 10^9$ K

(b) 2.0×10^9 K $< T < 3.0 \times 10^9$ K

(c) 3.0×10^9 K $< T < 4.0 \times 10^9$ K

(d) 4.0×10^9 K $< T < 5.0 \times 10^9$ K

@FAKE_JEE_X@RAJ_KUNET

44. Results of calculations for four different designs of a fusion reactor using D-D reaction are given below. Which of these is most promising based on Lawson criterion? **(IIT-JEE 2009)**

(*a*) Deuteron density = 2.0×10^{12} cm^{-3}, confinement time = 5.0×10^{-3} s

(*b*) Deuteron density = 8.0×10^{14} cm^{-3}, confinement time = 9.0×10^{-1} s

(*c*) Deuteron density = 4.0×10^{23} cm^{-3}, confinement time = 1.0×10^{-11} s

(*d*) Deuteron density = 1.0×10^{24} cm^{-3}, confinement time = 4.0×10^{-12} s

Match the Column

45. List-I shows different radioactive decay processes and List-II provides possible emitted particles. Match each entry in List-I with an appropriate entry from List-II, and choose the correct option.

List-I		List-II	
P.	$^{238}_{92}U \rightarrow ^{234}_{91}Pa$	1.	one α particle and one β^+ particle
Q.	$^{214}_{82}Pb \rightarrow ^{210}_{82}Pb$	2.	three β^- particle and one α particle
R.	$^{210}_{81}Tl \rightarrow ^{206}_{82}Pb$	3.	two β^- particle and one α particle
S.	$^{228}_{91}Pa \rightarrow ^{224}_{88}Ra$	4.	one α particle and one β^- particle
		5.	one α particle and two β^+ particle

C-60.2 W-22.79 UA-17.01 (JEE Adv. 2023)

(*a*) P → 4, Q → 3, R → 2, S → 1

(*b*) P → 4, Q → 1, R → 2, S → 5

(*c*) P → 5, Q → 3, R → 1, S → 4

(*d*) P → 5, Q → 1, R → 3, S → 2

46. Match the nuclear processes given in Column-I with the appropriate option(s) in Column-II. **(JEE Adv. 2015)**

Column-I		Column-II	
A.	Nuclear fusion	P.	absorption of thermal neutrons by $^{235}_{92}U$
B.	Fission in a nuclear reactor	Q.	$^{60}_{27}Co$ nucleus
C.	β-decay	R.	Energy production in stars via hydrogen conversion to helium
D.	γ-ray emission	S.	Heavy water
		T.	Neutrino emission

47. Match Column-I of the nuclear process with Column-II containing parent nucleus and one of the end products of each process and then select the correct answer using the codes given below the lists.

C-85.68 W-11.9 UA-2.42 (JEE Adv. 2013)

Column-I		Column-II	
P.	Alpha decay	1.	$^{15}_{8}O \longrightarrow ^{17}_{7}N + \ldots$
Q.	β^+ decay	2.	$^{238}_{92}U \longrightarrow ^{234}_{90}Th + \ldots$
R.	Fission	3.	$^{185}_{83}Bi \longrightarrow ^{184}_{82}Pb + \ldots$
S.	Proton emission	4.	$^{239}_{94}Pu \longrightarrow ^{140}_{57}La + \ldots$

Codes	P	Q	R	S
(*a*)	4	2	1	3
(*b*)	1	3	2	4
(*c*)	2	1	4	3
(*d*)	4	3	2	1

Numerical Types/Integer Types

48. In a radioactive decay process, the activity is defined as $A = -\frac{dN}{dt}$, where $N(t)$ is the number of radioactive nuclei at time t. Two radioactive sources, S_1 and S_2 have same activity at time $t = 0$. At a later time, the activities of S_1 and S_2 are A_1 and A_2, respectively. When S_1 and S_2 have just completed their 3rd and 7th half-lives, respectively, the ratio A_1/A_2 is_____.

C-42.49 W-42.34 UA-15.18 (JEE Adv. 2023)

49. In a radioactive decay chain reaction, $^{230}_{90}Th$ nucleus decays into $^{214}_{84}Po$ nucleus. The ratio of the number of α to number of β^- particles emitted in this process is_____.

C-46.09 W-14.82 UA-39.09 (JEE Adv. 2022)

50. Suppose a $^{226}_{88}Ra$ nucleus at rest and in ground state undergoes α-decay to a $^{222}_{86}Rn$ nucleus in its excited state. The kinetic energy of the emitted α particle is found to be 4.44 *MeV*. $^{222}_{86}Rn$ nucleus then goes to its ground state by γ-decay. The energy of the emitted γ-photon is_____ *keV*.

[Given: atomic mass of $^{226}_{88}Ra$ = 226.005 *u*, atomic mass of $^{222}_{86}Rn$ = 222.00 *u*, atomic mass of a particle = 4.000 *u*, 1 *u* = 931 *MeV*/c^2, *c* is speed of the light]

C-0.76, W-76.03, UA-23.2 (JEE Adv. 2019)

51. ^{131}I is an isotope of Iodine that β decays to an isotope of Xenon with a half-life of 8 days. A small amount of a serum labeled with ^{131}I is injected into the blood of a person. The activity of the amount of ^{131}I injected was 2.4×10^5 Becquerel (Bq). It is known that the injected serum will get distributed uniformly in the bloodstream in less than half an hour. After 11.5 *h*, 2.5 *ml* of blood is drawn from the person's body, and gives an activity of 115 *Bq*. The total volume of blood in the person's body, in liters is approximately (you may use $e^2 \approx 1 + x$ for $|x| << 1$ and $2 \approx 0.7$).

C-21.67 W-69.38 UA-8.95 (JEE Adv. 2017)

52. For a radioactive material, its activity A and rate of change of its activity R are defined as $A = -\frac{dN}{dt}$ and $R = -\frac{dA}{dt}$, where $N(t)$ is the number of nuclei at time t. Two radioactive source P(mean life τ) and Q(mean life 2τ) have the same activity at $t = 0$. Their rate of change of activities at $t = 2\tau$ are R_P and R_Q, respectively. If $\frac{R_P}{R_Q} = \frac{n}{e}$, then the value of n is **(JEE Adv. 2015)**

53. A nuclear power plant supplying electrical power to a village uses a radioactive material of half life T years as the fuel. The amount of fuel at the beginning is such that the total power requirement of the village is 12.5% of the electrical power available from the plant at that time. If the plant is able to meet the total power needs of the village for a maximum period of nT years, then the value of n is **(JEE Adv. 2015)**

@FAKE_INDEX_GRAVITON

54. A freshly prepared sample of a radioisotope of half-life 1386s has activity 10^3 disintegrations per second. Given that $\ln 2 = 0.693$, the fraction of the initial number of nuclei (expressed in nearest integer percentage) that will decay in the first 80s after preparation of the sample is **C-8.15 W-24.12 UA-67.73 (JEE Adv. 2013)**

Fill in the Blanks

55. Consider the reaction: ${}_1^2H + {}_1^2H \rightarrow {}_2^4He + Q$. Mass of the deuterium atom = 2.0141u. Mass of helium atom = 4.0024 u. This is a nuclear ..... reaction in which the energy Q released is ..... MeV. **(IIT-JEE 1996)**

56. In the nuclear process, ${}_6C^{11} \rightarrow {}_5B^{11} + \beta^+ + X$, X stands for ..... . **(IIT-JEE 1992)**

57. The radioactive decay rate of a radioactive element is found to be 10^3 disintegration/second at a certain time. If the half-life of the element is one second, the decay rate after one second is ..... and after three seconds is..... . **(IIT-JEE 1983)**

58. In the uranium radioactive series, the initial nucleus is ${}_{92}^{238}U$ and the final nucleus is ${}_{82}^{206}Pb$. When the uranium nucleus decays to lead, the number of α-particles emitted is ... and the number of β-particles emitted is ..... . **(IIT-JEE 1985)**

59. When boron nucleus (${}_5^{10}B$) is bombarded by neutrons, α-particles are emitted. The resulting nucleus is of the element ..... and has the mass number..... . **(IIT-JEE 1986)**

Subjective

60. A rock is 1.5×10^9 yr old. The rock contains ^{238}U which disintegrates to form ^{206}Pb. Assume that there was no ^{206}Pb in the rock initially and it is the only stable product formed by the decay. Calculate the ratio of number of nuclei of ^{238}U to that of ^{206}Pb in the rock. Half-life of ^{238}U is 4.5×10^9 yr. ($2^{1/3} = 1.259$) **(IIT-JEE 2004)**

61. A radioactive element decays by β-emission. A detector records n beta particles in 2 s and in next 2s it records $0.75n$ beta particles. Find mean life correct to the nearest whole number. Given $ln|2| = 0.6931$, $ln|3| = 1.0986$. **(IIT-JEE 2003)**

62. In a nuclear reactor ^{235}U undergoes fission liberating 200 MeV of energy. The reactor has a 10% efficiency and produces 1000 MW power. If the reactor is to function for 10 yr, find the total mass of uranium required. **(IIT-JEE 2001)**

63. A nucleus at rest undergoes a decay emitting an α-particle of de-Broglie wavelength, $\lambda = 5.76 \times 10^{-15}$ m. If the mass of the daughter nucleus is 223.610 amu and that of the α-particle is 4.002 amu. Determine the total kinetic energy in the final state. Hence obtain the mass of the parent nucleus in amu. **(IIT-JEE 2001)**

64. Nuclei of a radioactive element A are being produced at a constant rate α. The element has a decay constant λ. At time $t = 0$, there are N_0 nuclei of the element. **(IIT-JEE 1998)**
   (*a*) Calculate the number N of nuclei of A at time t.
   (*b*) If $\alpha = 2N_0\lambda$, calculate the number of nuclei of A after one half-life of A and also the limiting value of N as $t \rightarrow \infty$.

65. The element curium ${}_{96}^{248}Cm$ has a mean life of 10^{13}s. Its primary decay modes are spontaneous fission and α-decay, the former with a probability of 8% and the latter with a probability of 92%, each fission releases 200 MeV of energy. The masses involved in decay are as follows: **(IIT-JEE 1997)**
   ${}_{96}^{248}Cm = 248.072220$ u,
   ${}_{94}^{244}Pu = 244.064100$ u and ${}_2^4He = 4.002603$ u. Calculate the power output from a sample of 10^{20} Cm atoms. (1 u = 931 MeV/c^2)

66. At a given instant there are 25% undecayed radioactive nuclei in a sample. After 10 s the number of undecayed nuclei reduces to 12.5%. Calculate **(IIT-JEE 1996)**
   (*a*) mean life of the nuclei,
   (*b*) the time in which the number of undecayed nuclei will further reduce to 6.25% of the reduced number.

67. A small quantity of solution containing Na^{24} radio nuclide (half-life = 15 h) of activity 1.0 micro curie is injected into the blood of a person. A sample of the blood of volume 1 cm^3 taken after 5h shows an activity of 296 disintegrations per minute. Determine the total volume of the blood in the body of the person. Assume that the radioactive solution mixes uniformly in the blood of the person. (1 curie = 3.7×10^{10} disintegrations per second) **(IIT-JEE 1994)**

68. A nucleus X, initially at rest, undergoes alpha-decay according to the equation. **(IIT-JEE 1991)**
$$^{A}_{92}X \rightarrow {}^{228}_{Z}Y + \alpha$$
   (*a*) Find the values of A and Z in the above process.
   (*b*) The alpha particle produced in the above process is found to move in a circular track of radius 0.11m in a uniform magnetic field of 3 T. Find the energy (in MeV) released during the process and the binding energy of the parent nucleus X. Given that m (Y) = 228.03u; $m({}_0^1n) = 1.009$ u
   $m({}_2^4He) = 4.003$ u; $m({}_1^1H) = 1.008$ u.

69. There is a stream of neutrons with a kinetic energy of 0.0327 eV. If the half-life of neutrons is 700 s, what fraction of neutrons will decay before they travel a distance of 10 m? **(IIT-JEE 1986)**

OF AKASH SERIES OF AKASH EDUNET

ANSWER KEY

JEE-Main

1. [8.00]	2. (a)	3. [4]	4. [27]	5. (c)	6. (a)	7. (b)	8. (c)	9. [2]	10. [11]
11. (b)	12. (c)	13. (b)	14. (a)	15. (b)	16. (a)	17. (a)	18. (d)	19. (b)	20. (d)
21. [6]	22. [16]	23. [121]	24. (d)	25. (d)	26. [26]	27. [2.32 to 2.33]		28. (a,b,d)	29. [27]
30. (a,c,d)	31. (d)	32. (b)	33. (b)	34. (c)	35. (*)	36. [236]	37. (c)	38. (d)	39. (c)
40. [1]	41. (d)	42. [208]	43. [727]	44. (c)	45. (d)	46. [15]	47. (c)	48. (d)	49. (d)
50. (a)	51. [6]	52. (a)							

JEE-Advanced

1. (b)	2. [9]	3. (c)	4. (a)	5. (c)	6. (a,b,d)	7. (a,c,d)	8. (b,d)	9. (c,d)	10. (c)
11. (a)	12. (d)	13. (c)	14. (a)	15. [2.32 to 2.33]		19. (d)	20. (a)	21. (a)	22. (c)
23. (a)	24. (a)	25. (d)	26. (c)	27. (a)	28. (d)	29. (c)	30. (d)	31. (c)	32. (b)
33. (d)	34. (a)	35. (b)	36. (b)	37. (c)	38. (d)	39. (b)	40. (a,c)	41. (b,c)	42. (d)
43. (a)	44. (b)	45. (a)	46. A → (r, t); B → (p, s); C → (p, q, r, t); D → (p, q, r, t)				47. (c)	48. [16]	49. [2]
50. [135]	51. [5]	52. [2]	53. [3]	54. [4]					

EXPLANATIONS

JEE-Main

1. [8.00]

$$\text{As } V = \frac{kQ}{r} = \frac{k \cdot Ze}{r},$$

$$= \frac{9\times10^{9}\times50\times1.6\times10^{-19}}{9\times10^{-13}\times10^{-2}}$$

$$= 8 \times 10^{6}\text{V}$$

2. *(a)* $R_1 = \frac{R_2}{2}$

Radius of nucleus is given as,

$$R_0(A_1)^{1/3} = \frac{R_0}{2}(A_2)^{1/3}$$

$$A_1 = \frac{1}{8}A_2$$

$$A_1 = \frac{192}{8} = 24$$

3. [4]

For a nucleus, $R = R_0(A)^{1/3}$

Volume: $V = \frac{4}{3}\pi R^3$

$$R = R_0(A)^{1/3}$$

$$V = \frac{4}{3}\pi R_0^3 A$$

$$\Rightarrow \frac{V_2}{V_1} = \frac{A_2}{A_1} = 4$$

4. [27] As, $R = R_0A^{1/3}$

$$\Rightarrow R^3 \propto A$$

$$\Rightarrow \left(\frac{4.8}{4}\right)^3 = \frac{64}{A}$$

$$\Rightarrow \frac{64}{A} = 1.44\times1.2$$

$$\Rightarrow A = \frac{64}{1.44\times1.2} = \frac{1000}{x}$$

$$\Rightarrow x = \frac{144\times12}{64} = 27$$

5. *(c)* Conceptual

6. *(a)* Net force on the system is constant, so momentum is conserned.

$$p_i = p_f$$

$$0 = m_1u_1 + m_2u_2$$

$$\frac{u_1}{u_2} = -\frac{m_2}{m_1} = -\left[\frac{1}{2}\right] \text{ as } \frac{m_1}{m_2} = \frac{2}{1}$$

move in opposite direction with speed ratio 1:2

7. *(b)* Nuclear density of any element is independent of A.

8. *(c)* $\because$ Nuclear density $= \frac{Am}{\frac{4}{3}\pi R^3}$

Where A is the mass number and m is mass of one nucleon.

$$\because R = R_0A^{\frac{1}{3}}$$

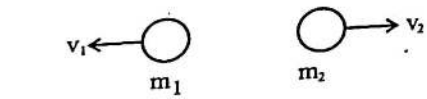
$$\Rightarrow R^3 = R_0^3A$$

$$\Rightarrow \text{Nuclear density} = \frac{Am}{\frac{4}{3}\pi R_0^3A}$$

$$\text{Nuclear density} = \frac{3m}{4\pi R_0^3}$$

$\therefore$ Nuclear density is independent of A

9. [2]



Given, $\frac{v_1}{v_2} = \frac{3}{2}$

Using conservation of linear momentum,

$$m_1v_1 = m_2v_2 \Rightarrow \frac{m_1}{m_2} = \frac{2}{3}$$

Since, Nuclear mass density remains constant

$$\Rightarrow \frac{m_1}{\frac{4}{3}\pi r_1^3} = \frac{m_2}{\frac{4}{3}\pi r_2^3}$$

$$\Rightarrow \left(\frac{r_1}{r_2}\right)^3 = \frac{m_1}{m_2}$$

@FAKE_CBSE_X @RAJ_EDUNET

$\Rightarrow \frac{r_1}{r_2} = \left(\frac{2}{3}\right)^{\frac{1}{3}}$

$\Rightarrow x = 2$ $\left[\because \frac{m_1}{m_2} = \frac{2}{3}\right]$

10. [11] Density of nuclei $= \frac{\text{mass of nuclei}}{\text{volume of nuclei}}$

$\rho = \frac{1.6\times10^{-27} A}{\frac{4}{3}\pi\left(1.5\times10^{-15}\right)^3 A} = 0.113\times10^{18}$

$\rho_w = 10^3$

Hence $\frac{\rho}{\rho_w} = 11.31\times10^{13}$

11. (*b*) Radius, $R = R_0 A^{1/3} \Rightarrow R \propto A^{1/3}$

$V \propto R^3$

$\therefore V \propto A$

And mass $\propto A$

So, density is independent of A.

12. (*c*) Radius of nucleus, $R = R_0 A^{1/3}$

$\delta = \frac{\text{mass}}{\text{Volume}} = \frac{mA}{\frac{4}{3}\pi R^3} = \frac{mA}{\frac{4}{3}\pi R_0^3 A}$

$\Rightarrow$ Density is independent of mass number

13. (*b*) Density of Nucleus $= \frac{\text{Mass}}{\text{Volume}}$

$= \frac{1.67\times10^{-27}\times A}{\frac{4}{3}\pi(1.3)^3\times10^{-45}\times A} \approx 10^{17}$

14. (*a*) Mass densities of all nuclei are same so their ratio is 1.

15. (*b*) Here we have given that the binding energy of nucleus is 18×10^8

$\Delta mc^2 = 18 \times 10^8$

$\Delta m \times 9 \times 10^{16} = 18 \times 10^8$

$\Delta m = 2 \times 10^{-8}\text{kg} = 20\ \mu\text{g}$

16. (*a*) Binding energy of the isotope $= \text{Dm}C_2$

$= (5\ \text{Mp} + 7\text{Mn} - \text{Mo})C_2$

17. (*a*) $\because$ Mass number $A \propto r^3 \Rightarrow r \propto A^{1/3}$.

$\therefore$ Surface energy per nucleon

$\propto \frac{r^2}{A} \propto \frac{1}{A^{1/3}}$

A is incorrect

Coulomb contribution to the binding energy is

$b_c = \frac{-a_2 Z(Z-1)}{A^{1/3}} \Rightarrow B$ is incorrect

Volume energy $\propto A \Rightarrow C$ is correct

As we consider only surface energy contribution then option is correct. $\Rightarrow D$ is correct.

In case of surface energy, only 3 interactions contribute to surface energy. $\Rightarrow E$ is incorrect.

18. (*d*) The nuclei ranging from mass number 30 to 170 have binding energy per nucleon almost same

19. (*b*) B.E of Helium $= (2m_p + 2m_N - m_{He}) \times 931.5$ MeV

$= 28.4$ MeV

20. (d) $Q = (m_A - m_B - m_D) \times c^2$

$= (238.05079 - 234.04363 - 4.00260)$

$= (0.00456\ c^2).u$

$0.00456c^2 \cdot 931.5 \frac{MeV}{c^2}$

$\left[\because 1u = 931\frac{MeV}{c^2}\right]$

$\Rightarrow 4.25$ MeV

21. [6] For nucleus A mass number $= 34$

Total binding energy

$= 1.2\times34 = 40.8 MeV$

For nucleus B mass number $= 26$

Total binding energy $= 1.8\times26 MeV$

$= 46.8 Me\ V$

Difference of BE $= 46.8 - 40.8 = 6\ MeV$

22. [16] Binding energy of system $= \frac{ke^2}{2r}$

$= 12.8 eV$

$\Rightarrow r = \frac{ke^2}{2\times12.8\times e}$

$r = \frac{9\times10^9\times1.6\times10^{-19}}{12.8\times2} = \frac{9\times10^{-10}}{16}$

23. [121] Initial binding energy $= 242 \times 7.6$ MeV,

Final binding energy $= (121 + 121) \times 8.1$ MeV,

$= 242 \times 8.1$ MeV

Total gain in binding energy = (Final binding energy – Initial binding energy)

$= 242\ (8.1 - 7.6) = 242 \times 0.5$

$= 121$ MeV

24. (*d*) $A \rightarrow {}^{105}B + {}^{115}C$

$Q = [105 \times 6.4 + 115 \times 6.4] - [220 \times 5.6]$ MeV

$Q = 176$ MeV

25. (*d*) $A + p \rightarrow B + b$

$Q = K_B + K_b - K_A$

$\Rightarrow Q + K_p = K_B + K_b$

$\Rightarrow Q + K_p > 0$

26. [26] Energy released in the given process = Binding energy of product - Binding energy of reactants

$= 7.6 \times 4 - (1.1 \times 2) \times 2$

$= 30.4 - 4.4$

$= 26$ MeV

27. [2.32 to 2.33]

${}^{16}_{7}N + {}^{4}_{2}He \rightarrow {}^{1}_{1}H + {}^{19}_{8}O$

28.....006 4.003 1.008 19.003

$4v_0 = 1v_1 + 19v_2 = 20v_2$ (For max loss of KE) $v_2 = \frac{v_0}{5}$

E required $= (1.008 + 19.003 - 16.006 - 4.003) \times 930 = 1.86$

$\frac{1}{2}4v_0^2 - \frac{1}{2}20v_2^2 = 1.86,$

$\frac{1}{2}4v_0^2 - 10\frac{v_0^2}{25} = 1.86$

$2v_0^2 - \frac{2}{5}v_0^2 = 1.86, \Rightarrow \frac{8}{5}v_0^2 = 1.86$

$v_0^2 = \frac{1.86\times5}{8}$

KE $= \frac{1}{2}4v_0^2 = 2v_0^2 = \frac{1.86\times5}{4}$

$= 2.325\ MeV$

28. (*a, b, d*) Binding energy of proton and neutron due to nuclear force is same. So difference in binding energy is only due to electrostatic P.E. and it is positive

$E_0^p - E_0^n$ = electrostatic P.E.

= Z × P.E. of one proton

$= \frac{1}{4\pi\varepsilon_0}\frac{(Z-1)e^2}{R}$

Where $R = R_0 A^{1/3} = \frac{1}{4\pi\varepsilon_0}\frac{(Z-1)e^2}{R_0 A^{\frac{1}{3}}}$

29. [27] Mass defect,

$\Delta m = [Zm_p + (A - Z)m_n - M_{Al}]$

$= [13 \times 1.00726 + 14 \times 1.00866 - 27.18846]$

$= [(13.09438 + 14.12124) - 27.18846]\ u$

$= [27.21562 - 27.1884]u$

$= 0.02716\ u$

$= 0.02716x\ J$

$= 27.16x \times 10^{-3}$

30. (*a, c, d*) $N \rightarrow P + Q$

Energy released

$= \left(m_N - m_P - m_Q\right)c^2 = \delta c^2$

This will be distributed kinetic energy of P and Q

$\Rightarrow E_P + E_Q = \delta c^2$

By conservationsssss of momentum

$v_p = \frac{p}{m_P}$ ← P Q → $\frac{p}{m_Q} = v_Q$ (m_P, m_Q)

So $\frac{v_P}{v_q} = \frac{m_Q}{m_P}$

$\therefore$ Kinetic energy be written as $KE = \frac{p^2}{2m}$

Hence divided in inverse ratio of masses.

Hence divided in inverse ratio of masses.

@FAKE_CBSE_X_@RAJEEV_BHARET

$$E_p = \frac{m_Q}{m_P + m_Q} c^2\delta$$

By equation (i) $\Rightarrow \frac{p^2}{2m_p} + \frac{p^2}{2m_q} = \delta c^2$

$$\Rightarrow \frac{p^2}{2\mu} = \delta c^2 \Rightarrow p = c\sqrt{2\mu\delta}$$

31. *(d)* Given: $m(Li) = 7.0160\ u$

$m(He) = 4.0026\ u$

$m(H) = 1.0079\ u$

${}^7_3Li + {}^1_1H \rightarrow 2{}^4_2He$

$\Delta m = (m_{Li} + m_H - 2m_{He})$

$= .0187\ u$

Energy liberates for 1g Li $= \frac{\Delta mc^2}{m(Li)}$

Energy liberates for 20g Li $= \frac{\Delta mc^2}{m(Li)} \times 20$

$$= \frac{0.0187 \times 931.5 \times 10^6 \times 1.6 \times 10^{-19} \times \frac{20}{7} \times 6.023 \times 10^{23}}{36 \times 10^5}$$

$= 1.33 \times 10^6$ kWh

32. *(b)* Δm should be positive

$(m_p + m_n) > m_d$

$\Rightarrow$ only (2) is possible

33. *(b)* $B.E. = (\Delta m)C^2$

$\Delta m = (50\ m_p + 70\ m_n) - (m_{Sn})$

$= (50 \times 1.00783 + 70 \times 1.00867) - (119.902199)$

$B.E. = \Delta m \times 931\ MeV$

$\Rightarrow B.E. = 1020.5631\ MeV$

$\Rightarrow \frac{B.E.}{Nucl.} = \frac{1020.5631}{120} = 8.5 MeV$

$= 8.5\ MeV$

34. *(c)* Power $= \frac{\text{Energy released}}{\text{time}}$

$$= \frac{2 \times 6.023 \times 10^{26} \times 200 \times 1.6 \times 10^{-19}}{30 \times 24 \times 60 \times 60 \times 235}$$

$= 60$ MW

35. (*) Energy $=$ (Binding Energy)$_{\text{Reactant}}$ $-$ (Binding Energy)$_{\text{Product}}$

$= 20 \times 8.03 - (8 \times 7.07 + 12 \times 7.86)$

$= 160.6 - (56.56 + 94.32) = 160.6 - 150.88 = 9.72$ MeV

Hence, 9.72 MeV released. No option is correct.

Hence, this question is bonus.

[236] Q = BEProduct – BERectant

$= 2(118)(8.6) - 236(7.6) = 236 \times 1 = 236$ MeV

37. *(c)* Given: $mn = 1.008665u$

${}_6C^{13} + \text{Energy} \rightarrow {}_6C^{12} + {}_0n^1$

$\therefore \Delta m = (12.000000 + 1.008665) - 13.003354$

$= -0.00531\ u$

As Binding Energy $= \Delta mc^2$

$\therefore$ Energy required $= 0.00531 \times 931.5$ MeV $= 4.95$ MeV

38. *(d)* ${}_3Li^6 + {}_0n^1 \rightarrow {}_2He^4 + {}_1H^3$

${}_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + {}_0n^1$

${}_3Li^6 + {}_1H^2 \rightarrow 2({}_2He^4)$

Energy released in process

$Q = \Delta mc^2$

$Q = [M(Li) + M({}_1H^2) - 2 \times M({}_2He^4)] \times 931.5$ MeV

$Q = [6.01690 + 2.01471 - 2 \times 4.00388] \times 931.5$ MeV

$Q = 22.216$ MeV

$Q = 22.22$ MeV

39. *(c)* (X) $\rightarrow$ (Y) + (Z) + (P)

M M/3 M/3 M/3

$$\Delta Mc^2 = \frac{1}{2}\frac{M}{3}V^2 + \frac{1}{2}\frac{M}{3}V^2 + \frac{1}{2}\frac{M}{3}V^2$$

The speed of a daughter nuclei

$$V = c\sqrt{\frac{2\Delta M}{M}}$$

40. [1]

Binding energy, $E = \Delta mc^2$

$= 0.4 \times 10^{-3} \times \left(3 \times 10^8\right)^2$

$= 3600 \times 10^7\ kWs$

$= \frac{3600 \times 10^7}{3600} kWh = 1 \times 10^7\ kWh$

41. *(d)* Balancing atomic number and mass number

${}^{235}_{92}U + {}^1_0n \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3{}^1_0n$

42. [208] ${}^{235}U \rightarrow {}^{140}Ce + {}^{94}Zr + n$

Disintegration energy

Q = (Total mass of reactant – Total mass of product).c^2

Q = [235.0439u – (139.9054u + 93.9063u + 1.0086 u)]c^2

$= 0.2236\ c^2$

$= 0.2236 \times 931$ MeV

Q = 208.1716 MeV

43. [727]

Reaction:

${}^{4}_{2}Hg \longrightarrow {}^{12}_{6}C + \gamma$ rays

Mass defect $= \Delta m = (3m_{He} - m_C)$

$= (3 \times 4.002603 - 12) = 0.007809\ u$

Energy released $= 931 \times \Delta m$ MeV

$= 727 \times 10^{-2}$ MeV

44. *(c)* Z in LHS $= 92$

A in LHS $= 236$

Z in RHS $= 56 + 36 = 92$

A in RHS $= 141 + 92 = 233$

So 3 neutrons are released.

45. *(d)* $E = mC^2$

$\Rightarrow E = (1 \times 10^{-3}) \times (3 \times 10^8)^2$ J

$\Rightarrow E = (10^{-3})(9 \times 10^{16})(6.241 \times 10^{18})$ eV

$E = 56.169 \times 10^{31}$ eV

$E \approx 5.6 \times 10^{26}$ MeV

46. [15]

Power generated $= \frac{N}{t} Q$

Where, $N \rightarrow$ Number of reaction/sec.

$Q = (3m_{He} - m_C)c^2$

$Q = (3 \times 4.0026 - 12)(3 \times 10^8)^2$

$Q = 7.266$ MeV

$\frac{N}{t} = \frac{\text{power}}{Q}$

$$= \frac{5.808 \times 10^{30}}{7.266 \times 10^6 \times 1.6 \times 10^{-19}}$$

$= 5 \times 10^{42}$

Thus, rate of conversion of ^{4}He into ^{12}C $= 15 \times 10^{42}$

Hence, $n = 15$

47. *(c)* In each fusion reaction, ${}^4_1H$ nucleus are used. Energy released per Nuclei of ${}^1_1H = \frac{26.7}{4}$ MeV

$\therefore$ Energy released by 2kg hydrogen (E_H)

$= \frac{2000}{1} \times N_A \times \frac{26.7}{4} MeV$

&

$\therefore$ Energy released by 2kg Uranium (E_V)

$= \frac{2000}{235} \times N_A \times 200 MeV$

So, The required ratio of energy released by hydrogen and Uranium

$\frac{E_H}{E_V} = 235 \times \frac{26.7}{4 \times 200} = 7.84$

$\therefore$ Approximately close to 7.62

@FAKE_CBSE @RAJ_EDUNET

48. (*d*) As a neutron has more rest mass than a proton, so it will require energy to decay into neutron.

49. (*d*) Density of nucleus is constant.

50. (*a*) The decay of a proton to neutron is possible only inside the nucleus.

51. [6]

No. of moles $= \frac{120}{240} = \frac{1}{2}$

No. of molecules $= \frac{1}{2} \times N_A$

Energy released $= \frac{1}{2} \times 6 \times 10^{23} \times 200\ MeV$

$= 6 \times 10^{25}\ MeV$

52. (*a*) Using conservation linear momentum, we can write

$$Mv = \frac{h}{\lambda} = \frac{h\nu}{c} \Rightarrow v = \frac{h\nu}{Mc}$$

Rest M ← v M γ-ray

JBC JBC

Loss of internal energy = Gain in kinetic energy + energy of gamma ray

$$= \frac{1}{2}Mv^2 + h\nu = \frac{1}{2}M\left(\frac{h\nu}{Mc}\right)^2 + h\nu = h\nu\left[1 + \frac{h\nu}{2Mc^2}\right]$$

JEE-Advanced

1. (*b*) Radius of a nucleus is given by $R = R_0 A^{1/3}$ (where $R_0 = 1.25 \times 10^{-15}$ m)

$= 1.25 A^{1/3} \times 10^{-15}$ m

Here A is the mass number. Mass of the uranium nucleus will be

$m = Am_p$ where m_p = mass of proton

$= A\ (1.67 \times 10^{-27}\ kg)$

$$\therefore \text{Density } \rho = \frac{\text{mass}}{\text{volume}} = \frac{m}{\frac{4}{3}\pi R^3}$$

$$= \frac{A(1.67 \times 10^{-27}\ kg)}{A(1.25 \times 10^{-15}\ m)^3}$$

or $\rho = 2.0 \times 10^{17}\ kg/m^3$

2. [9] $\frac{hc}{\lambda}\phi + ev$ ...(1)

$\frac{hc}{3\lambda}\phi + \frac{ev}{4}$ ...(2)

Dividing my Equation (1) by Equation (2)

$$3 = \frac{\phi + eV}{\phi + \frac{eV}{4}}$$

$$3\phi + = \frac{3eV}{4} = \phi + eV$$

$$\phi = \frac{eV}{8},\ \frac{hc}{\lambda} = \frac{eV}{8} + eV = \frac{9}{8}eV.$$

Therefore, $\phi = \frac{hc}{\lambda} = \frac{8}{9}\frac{hc}{\lambda}$.

So, $\phi = \frac{hc}{\lambda} = \frac{8}{9}\frac{hc}{\lambda}$.

$$\phi = \frac{1}{9}\frac{hc}{\lambda},\ \frac{hc}{\lambda_{th}} = \frac{hc}{9\lambda}$$

$\lambda_{th} = 9\lambda$

3. (*c*) Binding energy of nitrogen atom

$[8M_n + 7M_p - M_N] \times 931$

$= [8 \times 1.008665 + 7 \times 1.007825 - 15.000109] \times 931$

Binding energy of oxygen atom

$[8M_n + 8M_p - M_O] \times 931$

$= [7 \times 1.008665 + 8 \times 1.007825 - 15.003065] \times 931$

$\therefore$ Difference = 0.0037960 × 931 MeV ...(*i*)

Also, $E_O = \frac{3}{5} \times \frac{8 \times 7}{R} \times \frac{e^2}{4\pi\epsilon_0}$

$= \frac{3}{5} \times \frac{56}{R} \times 1.44\ MeV$

$E_N = \frac{3}{5} \times \frac{7 \times 6}{R} \times \frac{e^2}{4\pi\epsilon_0}$

$= \frac{3}{5} \times \frac{56}{R} \times 1.44\ MeV$

$\therefore E_O - E_N = \frac{3}{5} \times \frac{14}{R} \times 1.44\ MeV$ ...(*ii*)

From eq. (*i*) & (*ii*)

$\frac{3}{5} \times \frac{14}{R} \times 1.44 = 0.0037960 \times 931$

$\therefore$ R = 3.42 fm

4. (*a*)

5. (*c*) Energy is released in a process when total binding energy of the nucleus (= binding energy per nucleon × number of nucleons) is increased or we can say, when total binding energy of products is more than the reactants. By calculation we can see that only in option (*c*), this happens.

Given: $W \to 2Y$

Binding energy of reactants

= 120 × 7.5 = 900MeV

and binding energy of products

= 2 (60 × 8.5)

= 1020 MeV > 900 MeV

6. (*a, b, d*)

Binding energy of proton and neutron due to nuclear force is same. So difference in binding energy is only due to electrostatic P.E. and it is positive

$E_0^p - E_0^n$ = electrostatic P.E.

= Z × P.E. of one proton

$$= \frac{1}{4\pi\varepsilon_0}\frac{(Z-1)e^2}{R}$$

Where $R = R_0 A^{1/3} = \frac{1}{4\pi\varepsilon_0}\frac{(Z-1)e^2}{R_0 A^{\frac{1}{3}}}$

7. (*a, c, d*) $N \to P + Q$

Energy released

$= (m_N - m_P - m_Q)c^2 = \delta c^2$

This will be distributed kinetic energy of P and Q

$\Rightarrow E_p + E_Q = \delta c^2$

By conservation of momentum

$v_p = \frac{p}{m_P}$ ← P (mass m_p) Q (mass m_Q) →

$\frac{p}{m_Q} = v_Q$, So $\frac{v_P}{v_q} = \frac{m_Q}{m_P}$

Kinetic energy be written as $KE = \frac{p^2}{2m}$

Hence divided in inverse ratio of masses.

Hence divided in inverse ratio of masses.

$$E_p = \frac{m_Q}{m_P + m_Q}c^2\delta$$

By equation (*i*) $\Rightarrow \frac{p^2}{2m_p} + \frac{p^2}{2m_q} = \delta c^2$

$\Rightarrow \frac{p^2}{2\mu} = \delta c^2 \Rightarrow p = c\sqrt{2\mu\delta}$

8. (*b, d*) In fusion, two or more lighter nuclei combine to make a comparatively heavier nucleus.

In fission, a heavy nucleus breaks into two or more comparatively lighter nuclei.

Further, energy will be released in a nuclear process if total binding energy increases.

$\therefore$ Correct options are (*b*) and (*d*).

9. (*c, d*) Due to mass defect (which is finally responsible for the binding energy of the nucleus), mass of a nucleus is always less than the sum of masses of its constituent particles.

$^{20}_{10}Ne$ is made up of 10 protons plus 10 neutrons. Therefore, mass of $^{20}_{10}Ne$ nucleus, $M_1 < 10(m_p + m_n)$

@FAKE_CBSE_@RAJ_EDUNET

Up to iron, binding energy per nucleon normally increases with increase in mass number.

Hence, $\frac{[20(m_p+m_n)-M_2]c^2}{40} > \frac{10[m_p+m_N-M_1]c^2}{20}$

Solving this equation, we get

$M_1 > \frac{M_2}{2}$ or $2M_1 > M_2$ or $M_2 < 2M_1$

10. (*c*) [a] ${}_3Li^6 \rightarrow {}_2He^4 + {}_1H^2$

$\Delta m = [M_{Li} - M_{He} - M_H{}^2]$

$= [6.01513 - 4.002603 - 2.01410]$

$= -0.001573$ u

Δm is negative so reaction is not possible.

[b] ${}_{84}Po^{210} \rightarrow {}_{83}Bi^{209} + {}_1P^1$

Δ_m is negative so reaction is not possible.

[c] ${}_1H^2 + {}_2He^4 \rightarrow {}_3Li^6$

Δm is positive so reaction is possible.

[d] ${}_{30}Zn^{70} + {}_{34}Se^{82} \rightarrow {}_{64}Gd^{152}$

Δm is negative so reaction is not possible.

11. (*a*) ${}_{84}Po^{210} \longrightarrow {}_2He^4 + {}_{82}Pb^{206}$

Mass defect $\Delta m = (m_{Po} - M_{He} - m_{Pb})$

$= 0.005818$ u

$\therefore$ $Q = (\Delta m)\,(931.48)$ MeV $= 5.4193$ MeV $= 5419$ keV

From conservation of linear momentum,

$p_{Pb} = p_\alpha$

$\therefore$ $\sqrt{2m_{Pb}k_{Pb}} = \sqrt{2m_\alpha k_\alpha}$

or $\frac{k_\alpha}{k_{Pb}} = \frac{m_{Pb}}{m_\alpha} = \frac{206}{4}$

$\therefore$ $k_\alpha = \left(\frac{206}{206+4}\right)(k_{total})$

$= \left(\frac{206}{210}\right)(5419) = 5316$ keV

12. (*d*) If antineutrino had some mass then some of the energy will be shared by antineurino also. Therefore $K < 0.8 \times 10^6$ eV

13. (*c*) If energy of electron is nearly zero (can't be exactly zero), energy of anti-neutrino will be maximum and nearly equal to 0.8×10^6 eV

14. (*a*)

15. [2.32 to 2.33]

${}^{16}_7N$	+	${}^4_2He$	→	${}^1_1H$	+	${}^{19}_8O$
16.006		4.003		1.008		19.003

$4v_0 = 1v_1 + 19v_2 = 20v_2$ (For max loss of KE)

$v_2 = \frac{v_0}{5}$

E required $= (1.008 + 19.003 - 16.006 - 4.003) \times 930 = 1.86$

$\frac{1}{2}4v_0^2 - \frac{1}{2}20v_2^2 = 1.86$

$\frac{1}{2}4v_0^2 - 10\frac{v_0^2}{25} = 1.86$

$2v_0^2 - \frac{2}{5}v_0^2 = 1.86$

$\Rightarrow \frac{8}{5}v_0^2 = 1.86$, $\therefore v_0^2 = \frac{1.86\times5}{8}$

KE $= \frac{1}{2}4v_0^2 = 2v_0^2 = \frac{1.86\times5}{4}$

$= 2.325$ *MeV*

16. $2\ {}_1H^2 \longrightarrow {}_2He^4$

Binding energy of two deuterons,

$E_1 = 2\,[2 \times 1.1] = 4.4$ MeV

Binding energy of helium nucleus,

$E_2 = 4(7.0) = 28.0$MeV

$\therefore$ Energy released $\Delta E = E_2 - E_1$

$= (28 - 4.4)$MeV $= 23.6$MeV

17. Let at time $t = t$, number of nuclei of Y and Z are N_Y and N_Z. Then,

Rate equations of the populations of X, Y and Z are

$\left(\frac{dN_X}{dt}\right) = -\lambda_X N_X$ and $\left(\frac{dN_Y}{dt}\right)$

$= \lambda_X N_X - \lambda_Y N_Y$ $\left(\frac{dN_Z}{dt}\right) = \lambda_Y N_Y$

Given $N_Y(t) = \frac{N_0\lambda_X}{\lambda_X - \lambda_Y}[e^{-\lambda_Y t} - e^{-\lambda_X t}]$

For N_Y to be maximum

$\frac{dN_Y(t)}{dt} = 0$

i.e $\lambda_X N_X = \lambda_Y N_Y$ ...(*iv*) [from Eq. (*ii*)]

or

$\lambda_X(N_0e^{-\lambda_X t}) = \lambda_Y\frac{N_0\lambda_X}{\lambda_X - \lambda_Y}[e^{-\lambda_Y t} - e^{-\lambda_X t}]$

or

$\lambda_X(N_0e^{-\lambda_X t}) = \lambda_Y\frac{N_0\lambda_X}{\lambda_X - \lambda_Y}[e^{-\lambda_Y t} - e^{-\lambda_X t}]$

or $\frac{\lambda_X - \lambda_Y}{\lambda_Y} = \frac{e^{-\lambda_Y t}}{e^{-\lambda_X t}} - 1$

$\frac{\lambda_X}{\lambda_Y} = e^{(\lambda_X - \lambda_Y)t}$

or $(\lambda_X - \lambda_y)t\ln(e) = ln\left(\frac{\lambda_X}{\lambda_Y}\right)$

or $t = \frac{1}{\lambda_X - \lambda_Y}ln\left(\frac{\lambda_X}{\lambda_Y}\right)$

Substituting the values of λ_X and λ_Y, we have, $t = 16.489s$

The population of X at this moment,

$N_X = N_0e^{-\lambda_X t}) = (10^{20})\ e^{-(0.1)(16.48)}$

$= 1.92 \times 10^{19}$

$N_Y = \frac{N_X\lambda_X}{\lambda_Y}$ [From eq. (*iv*)]

$= (1.92\times10^{19})\frac{0.1}{(1/30)} = 5.76\times10^{19}$

$N_z = N_0 - N_X - N_Y$

$= 10^{20} - 1.92 \times 10^{19} - 5.76 \times 10^{19}$

$= 2.32 \times 10^{19}$

18. Mass defect in the given nuclear reaction:

$\Delta m = 2$(mass of deuterium) $-$ (mass of helium)

$= 2(2.0141) - (4.0026) = 0.0256$ amu

Therefore, energy released

$\Delta E = (\Delta m)\,(931.48)$ MeV$= 23.85$ MeV

$= 23.85 \times 1.6 \times 10^{-13}$ J $= 3.82 \times 10^{-12}$ J

Efficiency is only 25%, therefore,

25% of $\Delta E = \left(\frac{25}{100}\right)(3.82 \times 10^{-12})$ J

$= 9.55 \times 10^{-13}$ J

i.e. by the fusion of two deuterium nuclei, 9.55×10^{-13} J energy is available to the nuclear reactor.

Total energy required in one day to run the reactor with a given power of 200 MW:

$E_{Total} = 200 \times 10^6 \times 24 \times 3600$

$= 1.728 \times 10^{13}$ J

$\therefore$ Total number of deuterium nuclei required for this purpose

$n = \frac{E_{Total}}{\Delta E/2} = \frac{2\times1.728\times10^{13}}{9.55\times10^{-13}}$

$= 0.362 \times 10^{26}$

$\therefore$ Mass of deuterium required

= (Number of g-moles of deuterium required) $\times$ 2 g

$= \left(\frac{0.362\times10^{26}}{6.02\times10^{23}}\right) \times 2 = 120.26$ g.

19. (*d*) Out of 1000 nuclei of Q 60% may go α-decay

$\Rightarrow$ 600 nuclei may have α-decay

$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{20}$

$t = 1$ hour $= 60$ minutes

Using

$N = N_0e^{-\lambda t} = 600\times e^{\frac{\ln 2}{20}\times60}$ $N = 75$

$\Rightarrow$ 75 Nuclei are left after one hour

So, No. of nuclei decayed

$= 600 - 75 = 525$

@FAKE_CBSE_X @RAJ_EDUNET

20. (a) Parallel radioactive decay

$^{20}_{19}K \xrightarrow{\lambda_2 = 9\lambda} {}^{40}_{20}Ca$

$^{20}_{19}K \xrightarrow{\lambda_1 = \lambda} {}^{20}_{18}Ca$

$\lambda = \lambda_1 + \lambda_2 = 5 \times 10^{-10}$ per year

$N = N_0 e^{-\lambda t}$

$N_0 - N = N_{stable}$

$N = N_{radioactive}$

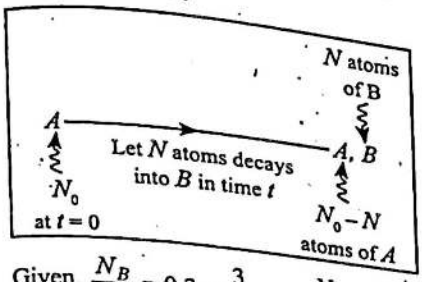
$\frac{N_0}{N} - 1 = 99 \; ; \; \frac{N_0}{N} = 100$

$\frac{N}{N_0} = e^{-\lambda t} = \frac{1}{100} \Rightarrow \lambda t = 2 \ln 10$

$= 4.6$

$t = 9.2 \times 10^9$ years

21. (a) Decay scheme is,



Given, $\frac{N_B}{N_A} = 0.3 = \frac{3}{10} \Rightarrow \frac{N_B}{N_A} = \frac{30}{100}$

So, $N_0 = 100 + 30 = 130$ atoms

By using $N = N_0 e^{-\lambda t}$

We have, $100 = 130 e^{-\lambda t}$

$\Rightarrow \frac{1}{1.3} = e^{-\lambda t} \Rightarrow log 13 = \lambda t$

$\Rightarrow log 1.3 = \frac{log 2}{T} \cdot t$

$\therefore t = \frac{T \cdot log(1.3)}{log 2}$

22. (c) Using the relation

$R = R_0 \left(\frac{1}{2}\right)^n$

Here, R is activity of radioactive substance, R_0 initial activity and n is the number of half lives.

$1 = 64 \left(\frac{1}{2}\right)^n$

Solving we get, $n = 6$

Now,

$t = n(t_{1/2}) = 6(18 \text{ days}) = 108 \text{ days}$

23. (a)

24. (a) Activity of $S_1 = \frac{1}{2}$ (activity of S_2)

or $\lambda_1 N_1 = \frac{1}{2}(\lambda_2 N_2)$

or $\frac{\lambda_1}{\lambda_2} = \frac{N_2}{2N_1}$ or $\frac{T_1}{T_2} = \frac{2N_1}{N_2}$

$\left(T = half - life = \frac{ln 2}{\lambda}\right)$

Given $N_1 = 2N_2$

$\therefore \frac{T_1}{T_2} = 4$

It is clear that the ratio of half lives of the two samples is 4 : 1, therefore half lives can be 20 ($4k$) years and 5 ($1k$) years respectively.

25. (d) Here, the activity of the radioactive sample reduces to half in 140 days. Therefore, the half life of the sample is 140 days. 280 days is two half lives. So before two half lives it's activity was $2^6 \times 6000 = 24000 dps$

26. (c) Gamma rays have no mass and charge. They are packets of energy / photons. Thus γ decay cannot result in change of mass no. or atomic no.

So, ${}^A X_Z \rightarrow {}^A X_Z + f$

27. (a) $R = R_0 \left(\frac{1}{2}\right)^n$

Here R = activity of radioactive substance after n half-lives $= \frac{R_0}{16}$

Substituting in Eq. (i), we get $n = 4$

$\therefore t = (n) t_{1/2} = (4)(100 \mu s) = 400 \mu s$

28. (d) The total number of atoms can neither remain constant (as in option *a*) nor can ever increase (as in options *b* and *c*). They will continuously decrease with time.

29. (c) During β-decay, a neutron is transformed into a proton and an electron. This is why atomic number (Z = number of protons) increases by one and mass number (A = number of protons + neutrons) remains unchanged during beta decay.

30. (d) $\frac{N_{x_1}(t)}{N_{x_2}(t)} = \frac{1}{e}$ or $\frac{N_0 e^{-10\lambda t}}{N_0 e^{-\lambda t}} = \frac{1}{e}$

(Initially, both have same number of nuclei say N_0)

or $e = e^{-\lambda t} / e^{-10\lambda t}$ or $e = e^{9\lambda t}$

or $9\lambda t = 1$ or $t = \frac{1}{9\lambda}$

31. (c) $(t_{1/2})_x = (t_{mean})_y$ or $\frac{0.693}{\lambda_x} = \frac{1}{\lambda_y}$

$\therefore \lambda_x = 0.693 \lambda_y, \lambda_x < \lambda_y$

Rate of decay $= \lambda N$

Initially number of atoms (N) of both are equal but since $\lambda_y > \lambda_x$; therefore, y will decay at a faster rate than x.

32. (b) Atomic number of neon is 10. By the emission of two α-particles, atomic number will be reduced by 4. Therefore, atomic number of the unknown element will be $Z = 10 - 4 = 6$

Similarly, mass number of the unknown element will be

$A = 22 - 2 \times 4 = 14$

Unknown nucleus is carbon ($A = 14$, $Z = 6$).

33. (d) Number of nuclei decreases exponentially

$N = N_0 e^{-\lambda t}$

and rate of decay $\left(-\frac{dN}{dt}\right) = \lambda N$

Therefore, decay process lasts upto $t = \infty$. Therefore, a given nucleus may decay at any time after $t = 0$.

34. (a) Penetrating power is maximum for γ-rays, then of β-particles and then α-particles because basically it depends on the velocity. However, ionization power is in reverse order.

35. (b) From $R = R_0 \left(\frac{1}{2}\right)^n$

we have, $1 = 64 \left(\frac{1}{2}\right)^n$

or $n = 6$ = number of half lives

$\therefore t = n \times t_{1/2} = 6 \times 2 = 12$ h

36. (b) As we know, $T_{1/2} = \frac{\ln 2}{\lambda}$ and $\tau = \frac{1}{\lambda}$.

37. (c) Following nuclear reaction takes place

${}_0n^1 \longrightarrow {}_1H^1 + {}_{-1}e^0 + \bar{\nu}$

$\bar{\nu}$ is antineutrino.

38. (d)

39. (b) Using $N = N_0 e^{-\lambda t}$

Where $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln(2)}{3.8}$

$\therefore \frac{N_0}{20} = N_0 e^{\frac{\ln(2)}{3.8} t}$

Solving this equation with the help of given data we find:

$t = 16.5$ days

40. (a, c) ${}^{232}_{90}Th$ is converting into ${}^{212}_{82}Pb$.

Change in mass number (A) = 20

$\therefore$ Number of α-particle emitted $= \frac{20}{4}$

$= 5$

Due to 5 α-particles, Z will change by 10 units.

Since, given change is 8, therefore number of β-particles emitted is 2.

@FAKE_CBSE_X@RAJ_BHUWNET

41. *(b, c)* In fusion reaction, two or more lighter nuclei combine to form a comparatively heavier nucleus.

42. *(d)*

43. *(a)* From conservation of mechanical energy, we have

$U_i + K_i = U_f + K_f$

$0 + 2(1.5\,kT) = \frac{1}{4\pi\varepsilon_0}\cdot\frac{(e)(e)}{d} + 0$

Substituting the values, we get

$T = 1.4 \times 10^9\,K$

44. *(b)* A reactor is termed successful, if $nt_0 > 5 \times 10^{14}\ s\ cm^{-3}$

45. *(a)*

- In β decay mass number decreases by 4 unit and atomic number decreases by 2 unit.
- In β^- decay mass number does not change but atomic number increases by 1 unit.
- In β^+ decay mass number does not change but atomic number decreases by 1 unit.

46. A → (r, t); B → (p, s); C → (p, q, r, t); D → (p, q, r, t)

47. *(c)* In α-decay mass number decreases by 4 and atomic number decreases by 2.

In β^+-decay mass number remains unchanged while atomic number decreases by 1.

In fission, parent nucleus breaks into all most two equal fragments.

In proton emission both mass number and atomic number decreases by 1.

48. *[16]*

Time(t)	Activity S_1	Activity S_2
0	A_0	A_0
τ	A_1	A_2

$\because A = A_0(0.5)^{t/t_{1/2}}$

$\therefore \frac{A_1}{A_2} = \frac{A_0(0.5)^{t/(t_{1/2})_1}}{A_0(0.5)^{t/(t_{1/2})_2}}$

$= \frac{(0.5)^3}{(0.5)^7} = 16$

49. *[2]* $Th_{90}^{230} \rightarrow Po_{21}^{484} + n\alpha_2^4 + m\beta_{-1}^0$

$230 = 214 + 4n$

$n = \frac{16}{4} = 4$

$90 = 84 + n \times 2 - m \times 1\ ;\ 90 = 84 + 4 \times 2 - m \times 1$

$m = 92 - 90 = 2$

Hence, $\frac{n}{m} = \frac{4}{2} = 2$

50. *[135]* $Ra^{226} \rightarrow Rn^{222} + \alpha$

$Q = (226.005 - 222 - 4)\,931\ MeV$

$= 4.655\ MeV$

$K_\alpha = \frac{A-4}{A}(Q-E)$

$4.44\,MeV = \frac{222}{226}(Q-E)$

$Q - E_\gamma = (4.44)\left(\frac{226}{222}\right)MeV$

$E_\gamma = 4.655 - 4.520 = .135\ MeV$

$= 135\ KeV$

51. *[5]* $\frac{t_1}{2} = 8\ \text{days} = 8 \times 24hr\ R_0 = 2.4 \times 10^5\ Bq$

$U_{sing}\ \frac{0.691}{t_{\frac{1}{2}}} \times t = ln\frac{R_0}{R}$

$\frac{0.692}{8\times 24} \times 11.5 = ln\frac{2.4\times 10^5}{R}$

$\frac{2.4\times 10^5}{R} = e^{0.041} = 1 + 0.041$

$R = \frac{2.4\times 10^5}{1.041} = 2.3\times 10^5\ Bq$ is in volume

$= 2.5ml\ 2.3 \times 10^5\ Bq$ is in volume

$= \frac{2.5}{115} \times 2.3 \times 10^5$

$= 0.05 \times 10^5 = 5 \times 10^3\ ml = 5$ liters

$2.3 \times 10^5\ Bq$ is in volume $= \frac{2.5}{115} \times 2.3 \times 10^5$

$= 0.05 \times 10^5$

52. *[2]* Let initial activity of both is A_0.

Then after time t, $A = A_0 e^{-\lambda t}$

$R = \frac{-dA}{dt} = \lambda A_0 e^{-\lambda t}$ ...(i)

For P, $\lambda = \frac{1}{\tau}$ and for Q, $\lambda = \frac{1}{2\tau}$ and $t = 2\tau$

Substituting in equation (i), we have

$\frac{R_P}{R_Q} = \frac{(A_0/\tau)e^{-(2\tau/\tau)}}{(A_0/2\tau)e^{-(2\tau/2\tau)}} = \frac{2}{e}$

$\therefore\ n = 2$

53. *[3]* Let initial power available from the plant is P_0. After time $t = nT$ or n half lives, this will become $\left(\frac{1}{2}\right)^n P_0$. Now, it is given that, $\left(\frac{1}{2}\right)^n P_0$. 12.5% of $P_0 = (0.125)P_0$

Solving this equation, we get $n = 3$

54. *[4]* $\frac{dN}{dt} = \lambda N_0 e^{-\lambda t}$

At $t = 0 : \lambda N_0 = 1000$

Given: $t_{1/2} = 1386s$

$\lambda = \frac{ln2}{t_{1/2}} = 5\times 10^{-4}\,s - 1\ \frac{N(t)}{N_0} = e^{-\lambda t}$

Put $t = 80s\ N(t)/N_0 = 0.96$

Decayed amount $= 0.04 = 4\%$

55. $Q = (\Delta m$ in atomic mass unit$) \times 931.4$ MeV

$= (2 \times$ mass of $_1H^2 -$ mass of $_2He^4) \times 931.4$ MeV

$= (2 \times 2.0141 - 4.0024) \times 931.4$ MeV

$Q \approx 24$ MeV (fusion)

56. $^{11}_{6}C \rightarrow {}^{11}_{5}B + \beta^+ + \gamma$ (neutrino)

57. $R = R_0\left(\frac{1}{2}\right)^n$

Here R_0 = initial activity = 1000 disintegration/s and n = number of half-lives.

At $t = 1$s, $n = 1$

$\therefore\ R = 10^3\left(\frac{1}{2}\right) = 500$ disintegration/s

At $t = 3$ s, $n = 3$

$\therefore\ R = 10^3\left(\frac{1}{2}\right) = 125$ disintegration/s

58. Number of α-particles emitted,

$n_1 = \frac{238 - 206}{4} = 8$

and number of β-particles emitted are say n_2, then

$92 - 8 \times 2 + n_2 = 82$

$\therefore\ n_2 = 6$

59. $_5B^{10} + {}_0n^1 \longrightarrow {}_2He^4 + {}_3Li^7$

Therefore, resulting nucleus is lithium and its mass number is 7.

60. Let N_0 be the initial number of nuclei of ^{238}U.

After time t, $N_U = N_0\left(\frac{1}{2}\right)^n$

Here n = number of half-lives

$= \frac{t}{t_{1/2}} = \frac{1.5\times 10^9}{4.5\times 10^9} = \frac{1}{3}$, $N_U = N_0\left(\frac{1}{2}\right)^{\frac{1}{3}}$

and $N_{Pb} = N_0 - N_U = N_0\left[1 - \left(\frac{1}{2}\right)^{1/3}\right]$

$\therefore\ \frac{N_U}{N_{Pb}} = \frac{\left(\frac{1}{2}\right)^{1/3}}{1 - \left(\frac{1}{2}\right)^3} = 3.861$

61. Let N_0 be initial number of nuclei at time $t = 0$.

The number of undecayed nuclei in time t is $N = N_0 e^{\lambda t}$

The number of nuclei decayed in time t is:

$n = N_0 - N_0 - N_0 e^{-\lambda t}$ ...(i)

The number of undecayed nuclei in next time t,

@RAJ CBSE X @RAJ EDUNET

$N' = Ne^{-\lambda t} = (N_0 e^{-\lambda t}) e^{-\lambda t} = N_0 e^{-2\lambda t}$ ...(ii)

Number of decayed nuclei in next time t,

$0.75n = N - N' = N_0 e^{-\lambda t} - N_0 e^{-2\lambda t}$

$= N_0 e^{-\lambda t}(1 - e^{-\lambda t})$ ...(iii)

Dividing Eq. (ii) by Eq. (i), we get:

$0.75 = e^{-\lambda t} \Rightarrow \frac{4}{3} = e^{\lambda t}$

Taking natural logarithm:

$$\ln\frac{4}{3} = \lambda t \Rightarrow \lambda = \frac{\ln\frac{4}{3}}{t}$$

Given $t = 2s$.

$$\therefore \lambda = \frac{\ln 4 - \ln 3}{2} = \frac{2\ln 2 - \ln 3}{2}$$

$$= \frac{2\times 0.6931 - 1.0986}{2} = 0.1438\ s^{-1}$$

Mean life, $\tau = \frac{1}{\lambda} = \frac{1}{0.1438} = 7s$ (whole number)

62. The reactor produces 1000MW power or 10^9J/s. The reactor is to function for 10 yr. Therefore, total energy which the reactor will supply in 10 yr is

E = (power) (time)

$= (10^9\ J/s)\ (10 \times 365 \times 24 \times 3600\ s)$

$= 3.1536 \times 10^{17}$ J

Since the efficiency of the reactor is only 10%, therefore actual energy needed is 10 times of it or 31.536×10^{18} J. One uranium atom liberates 200 MeV of energy or $200 \times 1.6 \times 10^{-13}$ J or 3.2×10^{-11} J of energy. So, number of uranium atoms needed are

$$\frac{3.1536\times 10^{18}}{3.2\times 10^{-11}} = 0.9855 \times 10^{29}$$

or number of kg-moles of uranium needed are

$$n = \frac{0.9855\times 10^{29}}{6.02\times 10^{26}} = 163.7$$

Hence, total mass of uranium required is

$m = (n)M = (163.7)\ (235)$ kg

or $m = 38470$ kg

or $m = 3.847 \times 10^4$ kg

63. Given mass of α-particle, $m = 4.002$ amu and mass of daughter nucleus, $M = 223.610$ amu,

de-Broglie wavelength of α-particle, $\lambda = 5.76 \times 10^{-15}$ m

So, momentum of α-particle would be

$$p = \frac{h}{\lambda} = \frac{6.63\times 10^{-34}}{5.76\times 10^{-15}}\ \text{kg-m/s}$$

or $p = 1.151 \times 10^{-19}$ kg-m/s

From law of conservation of linear momentum, this should also be equal to the linear momentum of the daughter nucleus (in opposite direction).

Let K_1 and K_2 be the kinetic energies of α-particle and daughter nucleus. Then total kinetic energy in the final state is

$K = K_1 + K_2$

$$= \frac{p^2}{2m} + \frac{p^2}{2M} = \frac{p^2}{2}\left(\frac{1}{m} + \frac{1}{M}\right)$$

$$K = \frac{p^2}{2}\left(\frac{M+m}{Mm}\right)$$

1 amu = 1.67×10^{-27} kg

Substituting the values, we get

$K = 10^{-12}$ J

$$K = \frac{10^{-12}}{1.6\times 10^{-13}} = 6.25\ \text{MeV}$$

or $K = 6.25$ MeV.

Mass defect, $\Delta m = \frac{6.25}{931.470}$

$= 0.0067$ amu

Therefore, mass of parent nucleus = mass of α-particle + mass of daughter nucleus + mass defect (Δm)

$= (4.002 + 223.610 + 0.0067)$ amu

$= 227.62$ amu

Hence, mass of parent nucleus is 227.62 amu.

64. (*a*) Let at time t, number of radioactive nuclei are N. Net rate of formation of nuclei of A

$$\frac{dN}{dt} = \alpha - \lambda N$$

or $\frac{dN}{\alpha - \lambda N} = dt$, or $\int_{N_0}^{N} \frac{dN}{\alpha - \lambda N} = \int_0^t dt$.

Solving this equation, we get

$$N = \frac{1}{\lambda}[\alpha - (\alpha - \lambda N_0)e^{-\lambda t}] \quad ...(i)$$

(*b*) (*i*) Substituting $\alpha = 2\lambda N_0$ and $t = t_{1/2} = \frac{\ln(2)}{\lambda}$ in Eq. (*i*) we get, $N = \frac{3}{2}N_0$

(*ii*) Substituting $\alpha = 2\lambda N_0$ and $t \to \infty$ in Eq. (*i*), we get

$$N = \frac{\alpha}{\lambda} = 2N_0 \text{ or } N = 2N_0$$

65. The reaction involved in α-decay is

$^{248}_{96}Cm \rightarrow {}^{244}_{94}Pu + {}^{4}_{2}He$

Mass defect

Δm = mass of $^{248}_{96}Cm$ − mass of $^{244}_{94}Pu$ − mass of $^{4}_{2}He$

$= (248.072220 - 244.064100 - 4.002603)u$

$= 0.005517u$

Therefore, energy released in a-decay will be

$E_\alpha = (0.005517 \times 931)\text{MeV} = 5.136\text{MeV}$

Similarly, $E_{fission} = 200\text{MeV}$ (given)

Mean life is given as $t_{mean} = 10^{13}\ s = 1/\lambda$

$\therefore$ Disintegration constant $\lambda = 10^{-13}\ s^{-1}$

Rate of decay at the moment when number of nuclei are 10^{20}

$= \lambda N = (10^{-13})\ (10^{20})$

$= 10^7$ disintegration per second

Of these disintegrations, 8% are in fission and 92% are in α-decay.

Therefore, energy released per second

$= (0.08 \times 10^7 \times 200 + 0.92 \times 10^7 \times 5.136)$ MeV $= 2.074 \times 10^8$ MeV

$\therefore$ Power output (in watt)

= energy released per second (J/s)

$= (2.074 \times 10^8)\ (1.6 \times 10^{-13})$

$\therefore$ Power output $= 3.32 \times 10^{-4}$ W

66. (*a*) In 10 s, number of nuclei has been reduced to half (25% to 12.5%).

Therefore, its half-life is $t_{1/2} = 10$ s

Relation between half-life and mean life is

$$t_{mean} = \frac{t_{1/2}}{\ln(2)} = \frac{10}{0.693}\text{s}$$

$t_{mean} = 14.43$ s

(*b*) From initial 100% to reduction till 6.25%, it takes four half lives.

$100\% \xrightarrow{t_{1/2}} 50\% \xrightarrow{t_{1/2}} 25\% \xrightarrow{t_{1/2}} 12.5\% \xrightarrow{t_{1/2}} 6.25\%$

$\therefore\ t = 4t_{1/2} = 4(10)\ s = 40\ s$

67. λ = Disintegration constant

$$\frac{0.693}{t_{1/2}} = \frac{0.693}{15}\text{h}^{-1}$$

Let R_0 = initial activity = 1microcurie $= 3.7 \times 10^4$ disintegrations per second.

r = Activity in 1 cm³ of blood at $t = 5$h

$= \frac{296}{60}$ disintegration per second

$= 4.93$ disintegration per second, and

R = Activity of whole blood at time $t = 5$h

Total volume of blood should be

$$V = \frac{R}{r} = \frac{R_0 e^{-\lambda t}}{r}$$

Substituting the values, we have

$$V = \left(\frac{3.7\times 10^4}{4.93}\right) e^{(0.0462)(5)}\ \text{cm}^3$$

$V = 5.95 \times 10^3$ cm³ or $V = 5.95$ L

68. (*a*) $A - 4 = 228$

$\therefore\ A = 232$

$92 - 2 = Z$ or $Z = 90$

(*b*) From the relation, $r = \frac{\sqrt{2Km}}{Bq}$

@FREE - CBSE - X @RAJ ARJUNET

$$K_\alpha = \frac{r^2B^2q^2}{2m}$$

$$= \frac{(0.11)^2(3)^2(2\times1.6\times10^{-19})^2}{2\times4.003\times1.67\times10^{-27}\times1.6\times10^{-13}}$$

$= 5.21$ MeV

From the conservation of momentum,

$P_Y = P_\alpha$ or $\sqrt{2K_Ym_Y} = \sqrt{2K_\alpha m_\alpha}$

$$\therefore\ K_Y = \left(\frac{m_\alpha}{m_Y}\right)K_\alpha = \frac{4.003}{228.03}\times5.21$$

$= 0.09$ MeV

∴ Total energy released $= K_\alpha + K_Y$

$= 5.3$ MeV

Total binding energy of daughter products

= [92 × (mass of proton) + (232 − 92) (mass of neutron)

$-(m_Y)-(m_\alpha)] \times 931.48$MeV

= [(92 × 1.008) + (140) (1.009) − 228.03

− 4.003] 931.48MeV

= 1828.5MeV

∴ Binding energy of parent nucleus = Binding energy of daughter products − energy released

= (1828.5 − 5.3)MeV = 1823.2MeV

69. Speed of neutrons

$$= \sqrt{\frac{2K}{m}}\left(\text{From } K = \frac{1}{2}mv^2\right)$$

or $v = \sqrt{\frac{2\times0.0327\times1.6\times10^{-19}}{1.675\times10^{-27}}}$

$= 2.5 \times 10^3$ m/s

Time taken by the neutrons to travel a distance of 10 m:

$$t = \frac{d}{v} = \frac{10}{2.5\times10^3} = 4.0\times10^{-3}\text{ s}$$

Number of neutrons decayed after time t:

$N = N_0(1 - e^{-\lambda t})$

∴ Fraction of neutrons that will decay in this time interval

$$= \frac{N}{N_0} = (1 - e^{-\lambda t}) = 1 - e^{-\frac{\ln(2)}{700}\times4.0\times10^{-3}}$$

$= 3.96 \times 10^{-6}$

@FAKE_CBSE X @RAJ_EDUNET

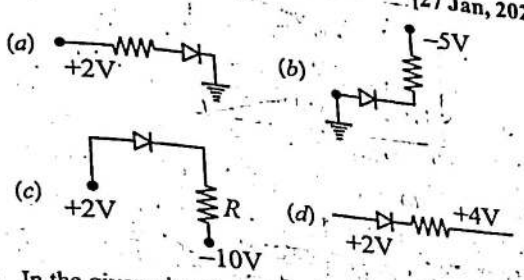
30 Semiconductor Electronics: Materials, Devices and Simple Circuits

Scan for ⊙ Sol.

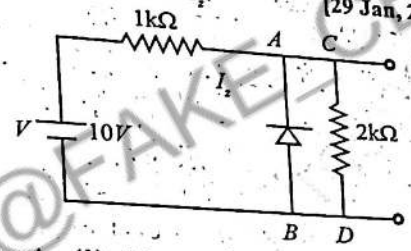
JEE-Main

Semiconductor, PN Junction and its Applications

1. Which of the following circuits is reverse-biased?
[27 Jan, 2024 (Shift-I)]

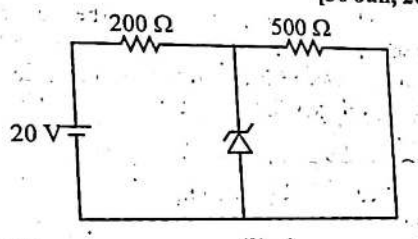


2. In the given circuit, the breakdown voltage of the Zener diode is 3.0 V. What is the value of I_z?
[29 Jan, 2024 (Shift-I)]



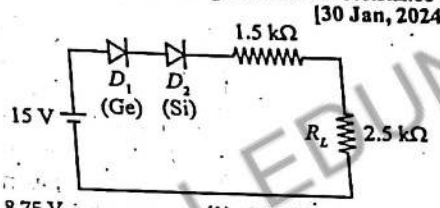
(a) 3.3 mA (b) 5.5 mA (c) 10 mA (d) 7 mA

3. A Zender diode of breakdown voltage 10V is used as a voltage regulator as shown in the figure. The current through the Zener diode is
[30 Jan, 2024 (Shift-I)]



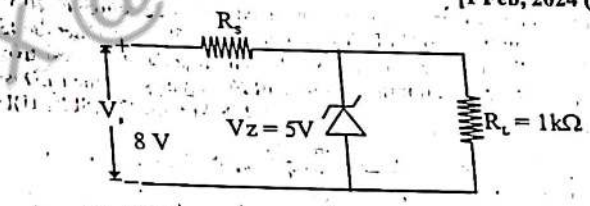
(a) 50 mA (b) 0
(c) 30 mA (d) 20 mA

4. In the given circuit, the voltage across load resistance (RL) is:
[30 Jan, 2024 (Shift-II)]



(a) 8.75 V (b) 9.00 V
(c) 8.50 V (d) 14.00 V

5. In the given circuit if the power rating of Zener diode is 10 mW, the value of series resistance Rs to regulate the input unregulated supply is:
[1 Feb, 2024 (Shift-I)]

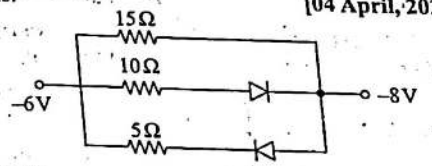


(a) 5kΩ (b) 10Ω
(c) 1kΩ (d) 10kΩ

6. Conductivity of a photodiode starts changing only if the wavelength of incident light is less than 660 nm. The band gap of photodiode is found to be $\left(\frac{X}{8}\right)eV$. The value of X is:
(Given, $h = 6.6 \times 10^{-34}$ Js, $e = 1.6 \times 10^{-19}$ C)
[1 Feb, 2024 (Shift-II)]

(a) 15 (b) 11 (c) 13 (d) 21

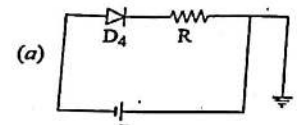
7. The value of net resistance of the network as shown in the given figure is:
[04 April, 2024 (Shift-I)]

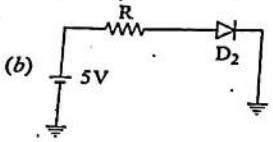


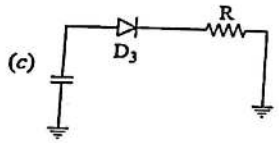
(a) $\left(\frac{5}{2}\right)\Omega$ (b) $\left(\frac{15}{4}\right)\Omega$
(c) 6 Ω (d) $\left(\frac{30}{11}\right)\Omega$

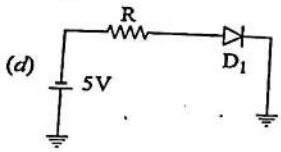
@FAKE_CASE_X@PAJEEBUNET

8. Which of the diode circuit shows correct biasing used for the measurement of dynamic resistance of p-n junction diode:
[04 April, 2024 (Shift-II)]

(a) 

(b) 

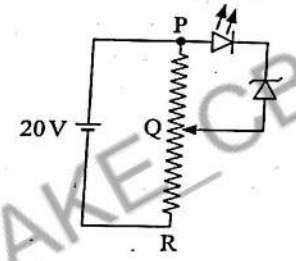
(c) 

(d) 

9. The acceptor level of a p-type semiconductor is 6 eV. The maximum wavelength of light which can create a hole would be : Given hc = 1242 eV nm.
[06 April, 2024 (Shift-II)]

(a) 407 nm (b) 414 nm
(c) 207 nm (d) 103.5 nm

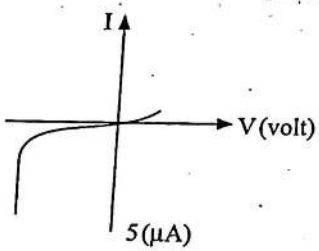
10. A potential divider circuit is connected with a dc source of 20 V, a light emitting diode of glow in voltage 1.8 V and a zener diode of breakdown voltage of 3.2 V. The length (PR) of the resistive wire is 20 cm. The minimum length of PQ to just glow the LED is _____ cm.
[08 April, 2024 (Shift-II)]



11. A light emitting diode (LED) is fabricated using GaAs semiconducting material whose band gap is 1.42 eV. The wavelength of light emitted from the LED is:
[09 April, 2024 (Shift-I)]

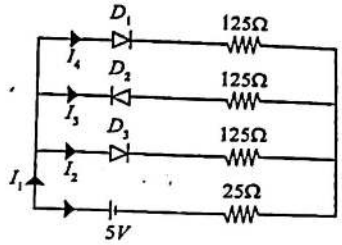
(a) 650 nm (b) 1243 nm
(c) 875 nm (d) 1400 nm

12. The I-V characteristics of an electronic device shown in the figure. The device is:
[09 April, 2024 (Shift-II)]



(a) a solar cell
(b) a transistor which can be used as an amplifier
(c) a zener diode which can be used as voltage regulator
(d) a diode which can be used as a rectifier

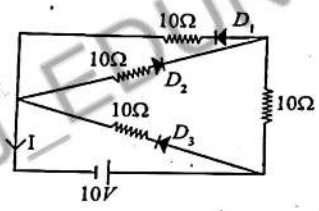
13. If each diode has a forward bias resistance of 25Ω in the below circuit,



Which of the following options is correct: **[10 Apr, 2023 (Shift-II)]**

(a) $\frac{I_3}{I_4}=1$ (b) $\frac{I_2}{I_3}=1$ (c) $\frac{I_1}{I_2}=1$ (d) $\frac{I_1}{I_2}=2$

14. In the given circuit, the current (I) through the battery will be:
[15 Apr, 2023 (Shift-I)]



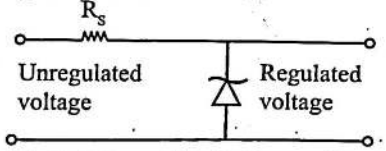
(a) 1.5 A (b) 1 A (c) 2.5 A (d) 2 A

15. Match the List-I with List-II
[01 Feb, 2023 (Shift-I)]

	List-I		List-II
A.	Intrinsic Semiconductor	I.	Fermi-level near conduction band
B.	n-type semiconductor	II.	Fermi-level at middle
C.	p-type semiconductor	III.	Fermi-level near valence band
D.	Metals	IV.	Fermi-level inside conduction band

Choose the correct answer from the options given below:
(a) A → I, B → II, C → III, D → IV
(b) A → II, B → I, C → III, D → IV
(c) A → II, B → III, C → I, D → IV
(d) A → III, B → I, C → II, D → IV

16. A zener diode of power rating 1.6 W is to be used as voltage regulator. If the zener diode has a breakdown of 8 V and it has to regulate voltage fluctuating between 3 V and 10 V. The value of resistance R_s for safe operation of diode will be:
[10 Apr, 2023 (Shift-I)]



(a) 13.3 Ω (b) 12 Ω (c) 10 Ω (d) 13 Ω

@FAKE_CBSE_@RAJ_EDUNET

17. **Statement-I:** When a *Si* sample is doped with Boron, it becomes *P* type and when doped by Arsenic it becomes *N*-type semi conductor such that *P*-type has excess of holes and *N*-type has excess of electrons.

Statement-II: When such *P*-type and *N*-type semi-conductors, are fused to make a junction, a current will automatically flow which can be detected with an externally connected ammeter.

In light of the above statements, choose the most appropriate answer from the options given below. **[25 Jan, 2023 (Shift-II)]**

(*a*) Both Statement-I and statement-II are incorrect
(*b*) Statement-I is incorrect but statement-II is correct
(*c*) Both Statement-I and statement-II are correct
(*d*) Statement-I is correct but statement-II is incorrect

18. The effect of increase in temperature on the number of electrons in conduction band (n_e) and resistance of a semiconductor will be as: **[31 Jan, 2023 (Shift-I)]**

(*a*) Both n_e and resistance decrease
(*b*) Both n_e and resistance increase
(*c*) n_e increases, resistance decreases
(*d*) n_e decreases, resistance increases

19. Given below are two statements : one is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**

Assertion (A): Photodiodes are preferably operated in reverse bias condition for light intensity measurement.

Reason (R): The current in the forward bias is more than the current in the reverse bias for a $p-n$ junction diode.

In the light of the above statement, choose the correct answer from the options given below: **[24 Jan, 2023 (Shift-I)]**

(*a*) *A* is false but *R* is true
(*b*) Both *A* and *R* are true but *R* is NOT the correct explanation of *A*
(*c*) *A* is true but *R* is false
(*d*) Both *A* and *R* are true and *R* is the correct explanation of *A*

20. Choose the correct statement about Zener diode: **[01 Feb, 2023 (Shift-II)]**

(*a*) It works as a voltage regulator in reverse bias and behaves like simple pn junction diode in forward bias.
(*b*) It works as a voltage regulator in both forward and reverse bias.
(*c*) It works a voltage regulator only in forward bias.
(*d*) It works as a voltage regulator in forward bias and behaves like simple pn junction diode in reverse bias.

21. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A): Diffusion current in a p-n junction is greater than the drift current in magnitude if the junction is forward biased.

Reason (R): Diffusion current in a p-n junction is from the *n*-side to the *p*-side if the junction is forward biased.

In the light of the above statements, choose the most appropriate answer from the options given below: **[06 Apr, 2023 (Shift-II)]**

(*a*) Both A and R are correct and R is the correct explanation of A
(*b*) Both A and R are correct but R is not the correct explanation of A
(*c*) A is correct but R is not correct
(*d*) A is not correct but R is correct

22. Given below are two statements : one is labeled as Assertion (A) and the other is labeled as Reason (R)

Assertion (A): Photodiodes are used in forward bias usually for measuring the light intensity.

Reason (R): For a p-n junction diode, at applied voltage *V* the current in the forward bias is more than the current in the reverse bias for $|V_z| > \pm V \geq |V_0|$ where V_0 is the threshold voltage and V_z is the breakdown voltage.

Choose the correct answer from the options given below: **[25 Jan, 2023 (Shift-I)]**

(*a*) Both *A* and *R* are true and *R* is the correct explanation of *A*
(*b*) Both *A* and *R* are true but *R* is NOT the correct explanation of *A*
(*c*) *A* is false but *R* is true
(*d*) *A* is true but *R* is false

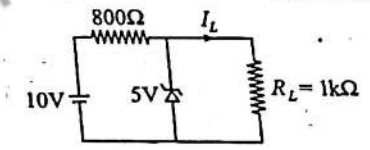
23. Which of the following Statement-Is not correct in the case of light emitting diodes?

A. It is a heavily doped p-n junction.
B. It emits light only when it is forward biased.
C. It emits light only when it is reverse biased.
D. The energy of the light emitted is equal to or slightly less than the energy gap of the semiconductor used.

Choose the correct answer from the options given below: **[29 Jan, 2023 (Shift-I)]**

(*a*) *C* and *D* (*b*) *A* (*c*) *C* (*d*) *B*

24. In the given circuit, the value of current I_L will be _____ mA. (When $R_L = 1k\Omega$) **[24 June, 2022 (Shift-II)]**



25. The photodiode is used to detect the optical signals. These diode are preferably operated in reverse biased mode because. **[25 June, 2022 (Shift-I)]**

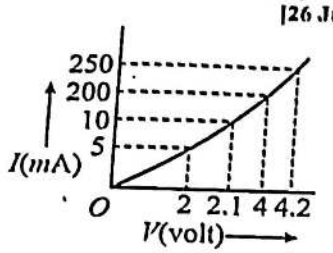
(*a*) Fractional change in majority carriers produce higher forward bias current
(*b*) Fraction change in majority carriers produce higher reverse bias current
(*c*) Fractional change in majority carriers produce higher forward bias current
(*d*) Fractional change in minority carriers produce higher reverse bias current

26. For using a multimeter to identify diode from electrical components. Choose the correct statement out of the following about the diode: **[28 June, 2022 (Shift-I)]**

(*a*) It is two terminal device which conducts current in both directions
(*b*) It is two terminal device which conducts current in one direction only
(*c*) It does not conduct current gives an initial deflection which decays to zero.
(*d*) It is three terminal device which conducts current in one direction only between central terminal and either of the remaining two terminals

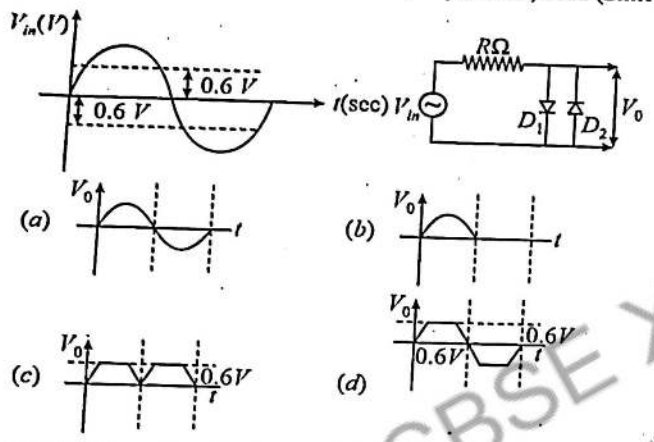
@FAKE_CBSE_X @RAJ_ENGINEER

27. The I–V characteristics of p–n junction diode in forward bias is shown in the figure. The ratio of dynamic resistance, corresponding to forward bias voltage of 2 V and 4 V respectively, is:
[26 June, 2022 (Shift-I)]

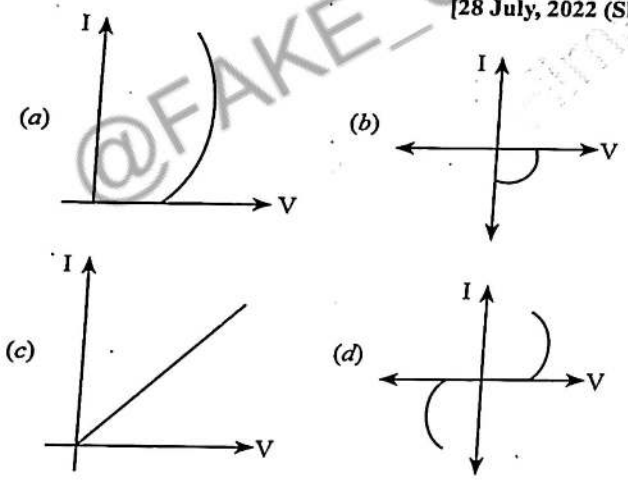


(a) 1 : 2 (b) 5 : 1
(c) 1 : 40 (d) 20 : 1

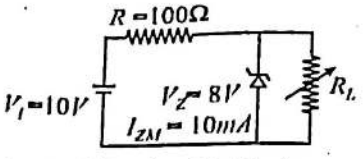
28. In the given circuit the input voltage V_{in} is shown in figure. The cut in voltage of p-n junction diode (D_1 or D_2) is 0.6 V. Which of the following output voltage (V_0) waveform across the diode is correct?
[28 June, 2022 (Shift-II)]



29. Identify the solar cell characteristics from the following options:
[28 July, 2022 (Shift-I)]

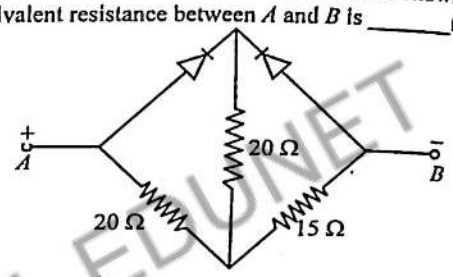


30. A zener of breakdown voltage $V_Z = 8$ V and maximum zener current $I_{ZM} = 10$ mA is subjected to an input voltage $V_i = 10$ V with series resistance $R = 100\ \Omega$. In the given circuit R_L represents the variable load resistance. The ratio of maximum and minimum value of R_L is _____
[28 June, 2022 (Shift-II)]



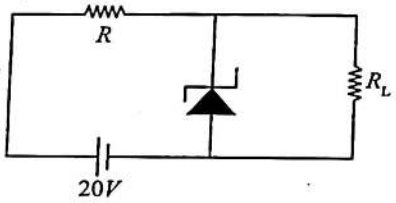
31. A potential barrier of 0.4 V exists across a p–n junction. An electron enters the junction from the n side with a speed of $6.0 \times 10^5 ms^{-1}$. The speed with which electron enters the p side will be $\frac{x}{3} \times 10^5 ms^{-1}$, the value of x is _____.
(Given mass of electron = 9×10^{-31} kg, charge on electron = 1.6×10^{-19} C)
[29 June, 2022 (Shift-II)]

32. Two ideal diodes are connected in the network as shown in figure. The equivalent resistance between A and B is _____Ω.



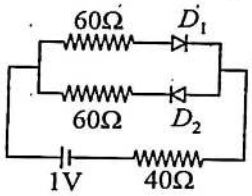
[25 July, 2022 (Shift-II)]

33. A 8 V Zener diode along with a series resistance R is connected across a 20 V supply (as shown in the figure). If the maximum Zener current is 25 mA, then the minimum value of R will be _____Ω.
[29 July, 2022 (Shift-II)]

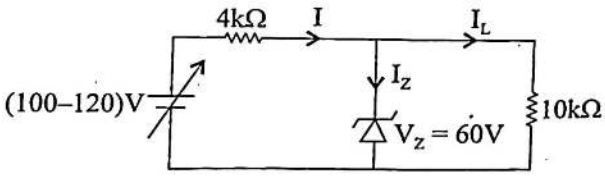


34. The energy band gap of semiconducting material to produce violet (wavelength = 4000Å) LED is _____ eV. (Round off to the nearest integer).
[25 July, 2022 (Shift-I)]

35. The cut off voltage of the diodes (shown in figure) in forward bias is 0.6 V. The current through the resistor of 40Ω is _____ mA
[27 June, 2022 (Shift-II)]



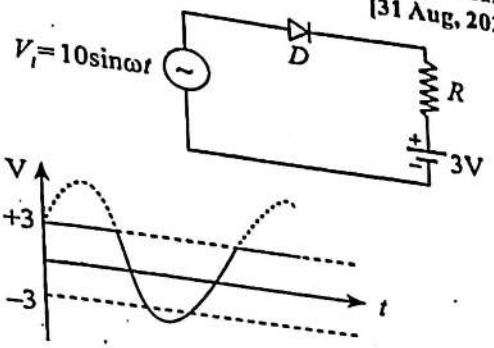
36. In the circuit shown below, maximum zener diode current will be _____mA.
[26 July, 2022 (Shift-I)]



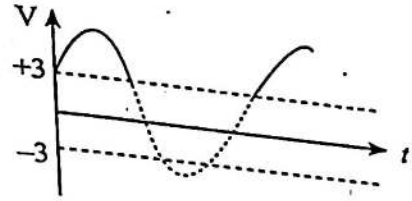
@FAKE_CBSE X @FAKE_EDUNET

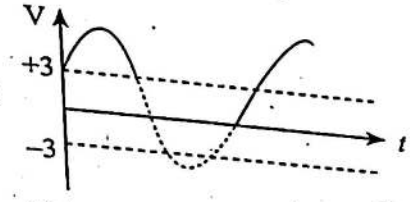
37. If the potential barrier across a p-n junction is 0.6 *V*. Then the electric field intensity, in the depletion region having the width of 6×10^{-6}m, will be _____ $\times 10^5$ *N/C*. [29 July, 2022 (Shift-I)]

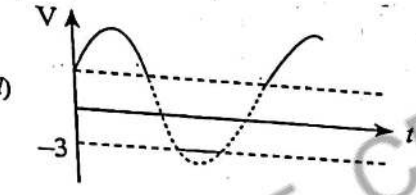
38. Choose the correct waveform that can represent the voltage across *R* of the following circuit, assuming the diode is ideal one: [31 Aug, 2021 (Shift-I)]



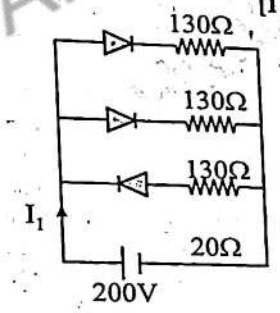
(a)

(b)


(c)


(d)


39. In the given figure, each diode has a forward bias resistance of 30Ω and infinite resistance in reverse bias. The current I_1 will be: [1 Sept, 2021 (Shift-II)]



(a) 3.75 A (b) 2.73 A (c) 2.35 A (d) 2 A

40. Zener breakdown occurs in a $P-n$ junction having *P* and *n* both: [24 Feb, 2021 (Shift-II)]

(a) Lightly doped and have wide depletion layer.
(b) Heavily doped and have wide depletion layer.
(c) Lightly doped and have narrow depletion layer.
(d) Heavily doped and have narrow depletion layer.

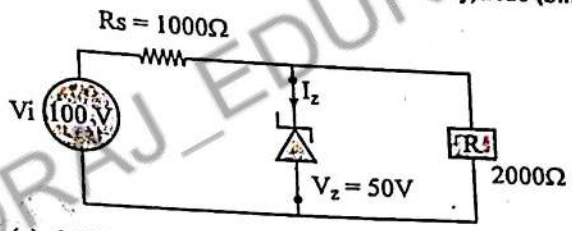
41. For extrinsic semiconductors; when doping level is increased; [25 Feb, 2021 (Shift-II)]

(a) Fermi-level of p and n-type semiconductors will not be affected.
(b) Fermi-level of p-type semiconductor will go upward and Fermi-level of n-type semiconductors will go downward.
(c) Fermi-level of p-type semiconductors will go downward and Fermi-level of n-type semiconductor will go upward.
(d) Fermi-level of both p-type and n-type semiconductors will go upward for $T > T_F K$ and downward for $T < T_F K$, where T_F is Fermi temperature.

42. Consider a situation in which reverse biased current of a particular $P-N$ junction increase when it is exposed to a light of wavelength ≤ 621 nm. During this process, enhancement in carrier concentration takes place due to generation of hole – electron pairs. The value of band gap is nearly. [22 July, 2021 (Shift-II)]

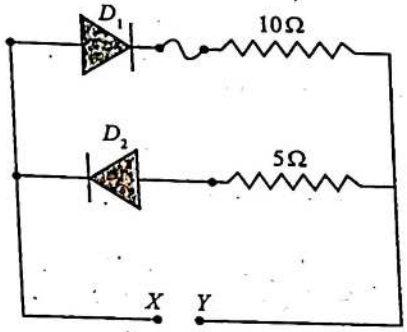
(a) 1 eV (b) 4 eV (c) 0.5 eV (d) 2 eV

43. For the circuit shown below, calculate the value of I_z: [20 July, 2021 (Shift-I)]



(a) 0.15 A (b) 0.1 A (c) 25 mA (d) 0.05 A

44. A 5 V battery is connected across the points *X* and *Y*. Assume D_1 and D_2 to be normal silicon diodes. Find the current supplied by the battery if the +*ve* terminal of the battery is connected to point *X*. [25 Feb, 2021 (Shift-I)]



(a) ~0.5 A (b) ~0.43 A (c) ~0.86 A (d) 1.5 A

45. LED is constructed from Ga – As - P semiconducting material. The energy gap of this LED is 1.9 eV. Calculate the wavelength of light emitted and its colour.
[$h = 6.63 \times 10^{-34}$ Js and $c = 3 \times 10^8$ ms^{-1}] [26 Feb, 2021 (Shift-I)]

(a) 654 nm and orange colour
(b) 1046 nm and blue colour
(c) 1046 nm and red colour
(d) 654 nm and red colour

@FAKE_CBSE_X_@RAJ_EDUNET

46. **Statement–I:** To get a steady dc output from the pulsating voltage received from a full wave rectifier we can connect a capacitor across the output parallel to the load RL.

Statement–II: To get a steady dc output from the pulsating voltage received from a full wave rectifier we can connect an inductor in series with RL.

In the light of the above statements, choose the most appropriate answer from the options given below: **[31 Aug, 2021 (Shift-II)]**

(a) Statement-I is false but Statement-II is true

(b) Statement-I is true but Statement-II is false

(c) Both Statement-I and Statement-II are true

(d) Both Statement-I and Statement-II are false

47. **Statement-I:** By doping silicon semiconductor with pentavalent material, the electrons density increases.

Statement-II: The *n*-type semiconductor has net negative charge.

[26 Aug, 2021 (Shift-I)]

In the light of the above statements, choose the most appropriate answer from the options given below:

(a) Both Statement-I and Statement-II are true

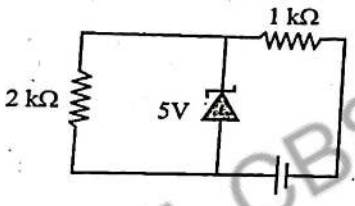
(b) Statement-I is true but Statement-II is false

(c) Statement-I is false but Statement-II is true

(d) Both Statement-I and Statement-II are false

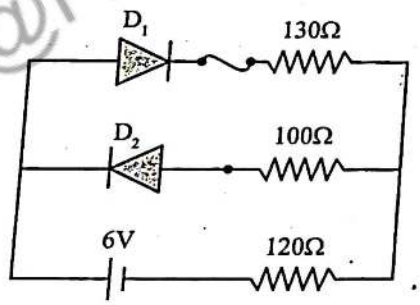
48. In connection with the circuit drawn below, the value of current flowing through 2 kΩ resistor is_____$\times 10^{-4}$A.

[24 Feb, 2021 (Shift-I)]



49. The circuit contains two diodes each with a forward resistance of 50 Ω and with infinite reverse resistance. If the battery voltage is 6 *V*, the current through the 120Ω resistance is _____ m A.

[26 Feb, 2021 (Shift-I)]

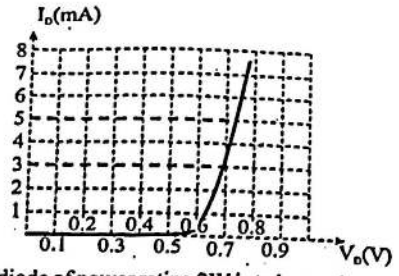


50. The value of power dissipated across the zener diode (Vz = 15V) connected in the circuit as shown in the figure is $x \times 10^{-1}$ watt. The value of x, to the nearest integer, is _____.

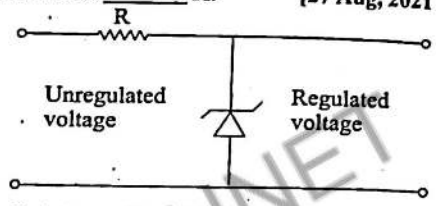
[16 Mar, 2021 (Shift-I)]

51. For the forward biased diode characteristics shown in the figure, the dynamic resistance at I_D = 3mA will be _____Ω.

[20 July, 2021 (Shift-II)]

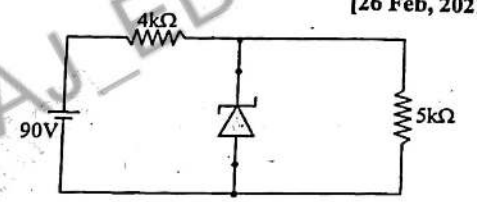


52. A zener diode of power rating 2W is to be used as a voltage regulator. If the zener diode has a breakdown of 10 V and it has to regulate voltage fluctuated between 6 V and 14 V, the value of R_s for safe operation should be _____ Ω. **[27 Aug, 2021 (Shift-II)]**

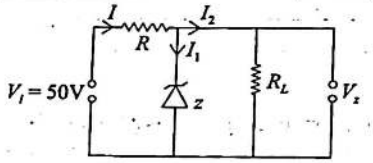


53. The zener diode has a V_z = 30 *V*. The current passing through the diode for the following circuit is _____ *mA*.

[26 Feb, 2021 (Shift-II)]



54. In a given circuit diagram, a 5 V zener diode along with a series resistance is connected across a 50 V power supply. The minimum value of the resistance required, if the maximum zener current is 90 mA be _____ Ω. **[22 July, 2021 (Shift-II)]**

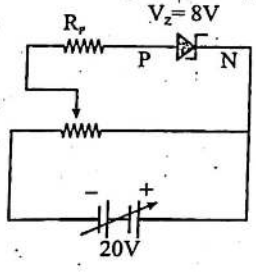


55. In a semiconductor, the number density of intrinsic charge carriers at 27°C is $1.5 \times 10^{16}/m^3$. If the semiconductor is doped with impurity atom, the hole density increases to $4.5 \times 10^{22}/m^3$. The electron density in the doped semiconductor is _____ $\times 10^9/m^3$.

[25 July, 2021 (Shift-II)]

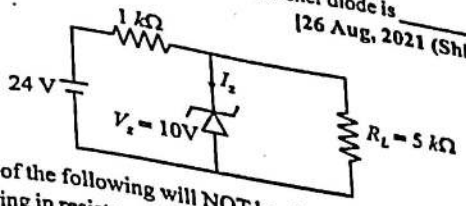
56. A zener diode having zener voltage 8V and power dissipation rating of 0.5W is connected across a potential divider arranged with maximum potential drop across zener diode is as shown in the diagram. The value of protective resistance R_p is _____ Ω.

[20 July, 2021 (Shift-II)]



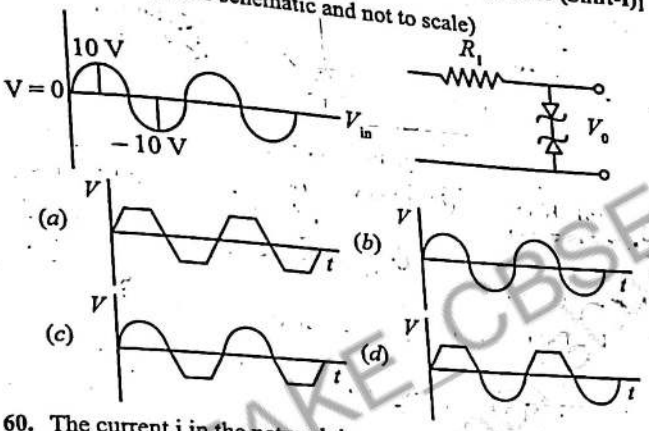
@FAKE_CBSE X @RAJ_EDUNET

57. For the given circuit, the power across zener diode is _____ mW.
[26 Aug, 2021 (Shift-II)]

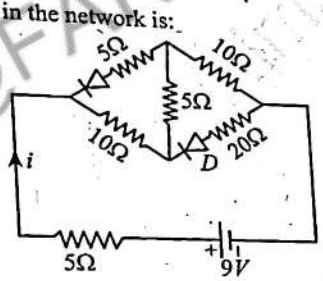


58. Which of the following will NOT be observed when a multimeter (operating in resistance measuring mode) probes connected across a component, are just reversed? [3 Sep, 2020 (Shift-II)]
(a) Multimeter shows a deflection, accompanied by a splash light out of connected component in one direction and NO deflection on reversing the probes if the chosen component is LED.
(b) Multimeter shows NO deflection in both cases i.e. before and after reversing the probes if the chosen component is metal wire.
(c) Multimeter shows NO deflection in both case i.e. before and after reversing the probes if the chosen component is capacitor.
(d) Multimeter shows an equal deflection in both cases i.e. before and after reversing the probes if the chosen component is resistor.

59. Take the breakdown voltage of the zener diode used in the given circuit as 6V. For the input voltage shown in figure below, the time variation of the output voltage is: [04 Sep, 2020 (Shift-I)]
(Graphs drawn are schematic and not to scale)



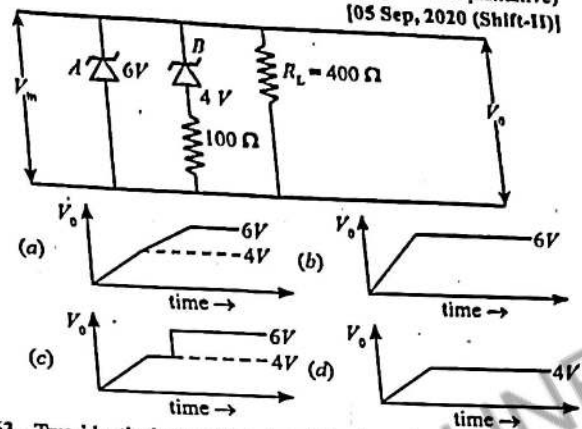
60. The current i in the network is:



[9 Jan, 2020 (Shift-II)]
(a) 0.6 A (b) 0 A (c) 0.2 A (d) 0.3 A

61. If a semiconductor photodiode can detect a photon with a maximum wavelength of 400 nm, then its band gap energy is_____
[Planck's constant $h = 6.63 \times 10^{-34}$ m/s, Speed of light $c = 3 \times 10^8$ Js.]
[3 Sep, 2020 (Shift-II)]
(a) 1.1 eV (b) 2.0 eV (c) 3.1 eV (d) 1.5 eV

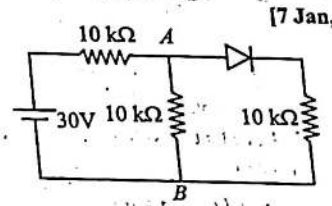
62. Two Zener diodes (A and B) having breakdown voltages of 6 V and 4 V respectively, are connected as shown in the circuit below. The output voltage V_0 variation with input voltage linearly increasing with time, is given by: ($V_{input} = 0$ V at $t = 0$) (figures are qualitative)
[05 Sep, 2020 (Shift-II)]



63. Two identical capacitors A and B, charged to the same potential $5V$ are connected in two different circuits as shown below at time $t = 0$. If the charge on capacitors A and B at time $t = CR$ is Q_A and Q_B respectively, then (Here e is the base of natural logarithm)
[9 Jan, 2020 (Shift-II)]
(a) $Q_A = VC, Q_B = CV$ (b) $Q_A = \frac{VC}{e}, Q_B = \frac{CV}{2}$
(c) $Q_A = VC, Q_B = \frac{VC}{e}$ (d) $Q_A = \frac{VC}{2}, Q_B = \frac{VC}{e}$

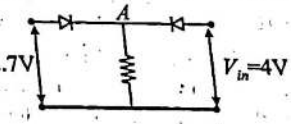
64. When a diode is forward biased, it has a voltage drop of 0.5 V. The safe limit of current through the diode is 10 mA. If a battery of emf 1.5 V is used in the circuit, the value of minimum resistance to be connected in series with the diode so that the current does not exceed the safe limit is [03 Sep, 2020 (Shift-I)]
(a) 100 Ω (b) 200 Ω (c) 50 Ω (d) 300 Ω

65. In the figure, potential difference between A and B is:
[7 Jan, 2020 (Shift-II)]



(a) 5 V (b) 10 V (c) zero (d) 15 V

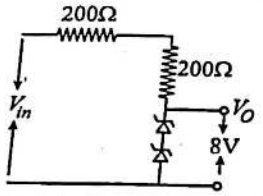
66. Both the diodes used in the circuit shown are assumed to be ideal and have negligible resistance when these are forward biased, built in potential in each diode is 0.7 V. For the input voltages shown in the figure, the voltage (in volts) at point A is ___
[9 Jan, 2020 (Shift-I)]



@FAKE_CBSE_X@RAJ_FB.NET

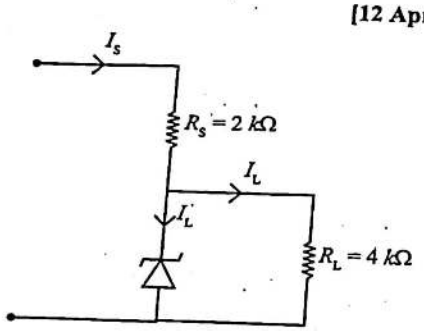
67. The circuit shown is working as a 8V dc regulated voltage source. When 12V is used as input, the power dissipated (in mW) in each diode is _____ (considering both Zener diodes are identical)

[9 Jan, 2020 (Shift-II)]



68. Figure shown a DC voltage regulator circuit, with a Zener diode of breakdown voltage = 6 *V*. If the unregulated input voltage varies between 10 *V* to 16 *V*, then what is the maximum Zener current?

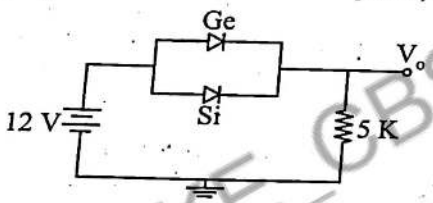
[12 Apr, 2019 (Shift-II)]



(*a*) 2.5 mA (*b*) 3.5 mA
(*c*) 7.5 mA (*d*) 1.5 mA

69. Ge and Si diodes start conducting at 0.3 V and 0.7 V respectively. In the following figure if Ge diode connection are reversed, the value of V_o changes by: (assume that the Ge diode has large breakdown voltage)

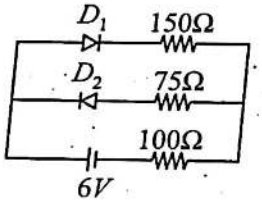
[9 Jan, 2019 (Shift-II)]



(*a*) 0.8 V (*b*) 0.6 V
(*c*) 0.2 V (*d*) 0.4 V

70. The circuit shown below cotains two ideal diodes, each with a forward resistance of 50Ω. If the battery voltage is 6V, the current through the 100Ω resistance (in Amperes) is

[11 Jan, 2019 (Shift-II)]



(*a*) 0.036 (*b*) 0.020
(*c*) 0.027 (*d*) 0.030

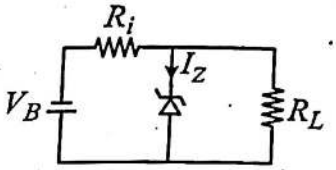
71. Mobility of electron in a semiconductor is defined as the ratio of their drift velocity to the applied electric field. If, for an n-type semiconductor, the density of electrons is 10^{19} m^{-3} and their mobility is 1.6 $m^2/(V.s)$ then the resistivity of the semiconductor (since it is an *n*-type semiconductor contribution of holes is ignored) is close to:

[9 Jan, 2019 (Shift-I)]

(*a*) 2 Ωm (*b*) 4 Ωm (*c*) 0.4 Ωm (*d*) 0.2 Ωm

72. The figure represents a voltage regulator circuit using a Zener diode. The breakdown voltage of the Zener diode is 6V and the load resistance is $R_L = 4\ k\Omega$. The series resistance of the circuit is $R_i = 1k\Omega$. If the battery voltage V_B varies from 8V to 16V, what are the minimum and maximum values of the current through Zener diode

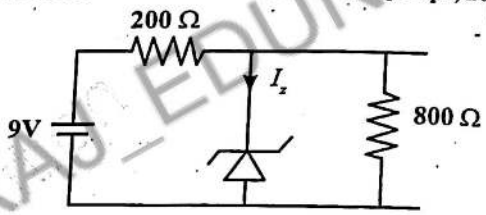
[10 Apr, 2019 (Shift-II)]



(*a*) 0.5 mA ; 6 mA
(*b*) 0.5 mA ; 8.5 mA
(*c*) 1.5 mA ; 8.5 mA
(*d*) 1 mA : 8.5 mA

73. The reverse breakdown voltage of a Zener diode is 5.6 V in the given circuit.

[8 Apr, 2019 (Shift-I)]



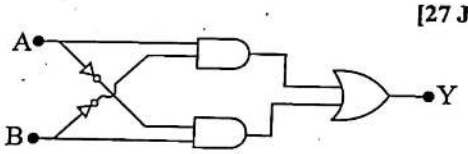
The current I_z, through the Zener is:

(*a*) 10 mA (*b*) 15 mA (*c*) 7 mA (*d*) 17 mA

Logic Gates

74. The truth table of the given circuit diagram is:

[27 JAN, 2024 (Shift-II)]



(*a*)

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

(*b*)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

(*c*)

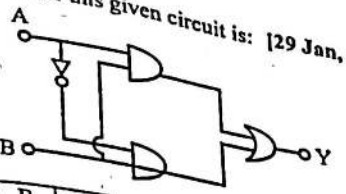
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

(*d*)

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

@FAKE_CBSE_X_@RAJ_EDUNET

75. The truth table for this given circuit is: [29 Jan, 2024 (Shift-II)]



(a)

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

(b)

A	B	Y
0	0	0
0	1	1
1	0	0
1	1	1

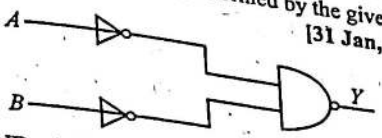
(c)

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

(d)

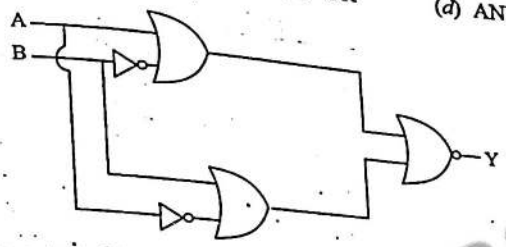
A	B	Y
0	0	1
0	1	0
1	0	1
1	1	0

76. Identify the logic operation performed by the given circuit. [31 Jan, 2024 (Shift-I)]



(a) NAND (b) NOR (c) OR (d) AND

77.



The output of the given circuit diagram is [31 Jan, 2024 (Shift-II)]

(a)

A	B	Y
0	0	0
1	0	0
0	1	0
1	1	1

(b)

A	B	Y
0	0	0
1	0	1
0	1	1
1	1	0

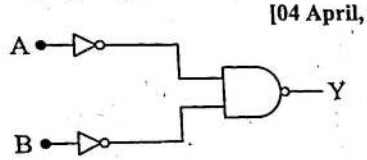
(c)

A	B	Y
0	0	0
1	0	0
0	1	0
1	1	0

(d)

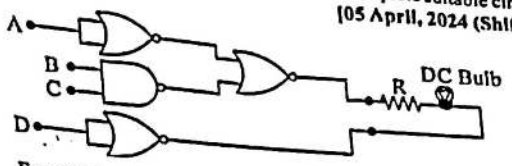
A	B	Y
0	0	0
1	0	0
0	1	1
1	1	0

78. Identify the logic gate given in the circuit: [04 April, 2024 (Shift-II)]



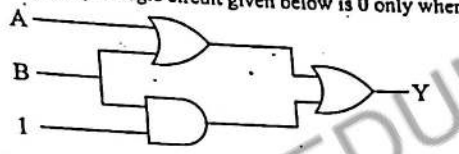
(a) NAND - gate (b) OR - gate
(c) AND gate (d) NOR gate

79. Following gates section is connected in a complete suitable circuit. [05 April, 2024 (Shift-I)]



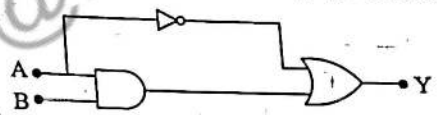
For which of the following combination, bulb will glow (ON):
(a) $A = 0, B = 1, C = 1, D = 1$
(b) $A = 1, B = 0, C = 0, D = 0$
(c) $A = 0, B = 0, C = 0, D = 1$
(d) $A = 1, B = 1, C = 1, D = 0$

80. The output (Y) of logic circuit given below is 0 only when :



(a) $A = 1, B = 0$
(b) $A = 0, B = 0$
(c) $A = 1, B = 1$
(d) $A = 0, B = 1$

81. The correct truth table for the following logic circuit is:



Options: [06 April, 2024 (Shift-I)]

(a)

A	B	Y
0	0	0
0	1	1
1	0	0
1	1	1

(b)

A	B	Y
0	0	1
0	1	1
1	0	0
1	1	1

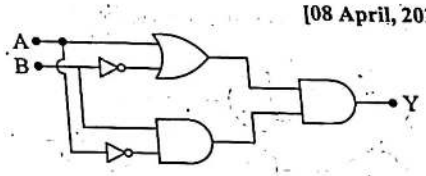
(c)

A	B	Y
0	0	1
0	1	1
1	0	0
1	1	0

(d)

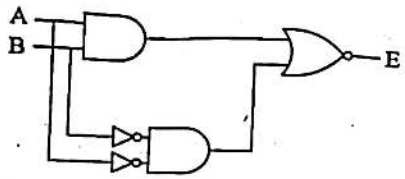
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

82. The output Y of following circuit for given inputs is: [08 April, 2024 (Shift-I)]



(a) $A \cdot B(A + B)$ (b) $A \cdot B$
(c) 0 (d) $\overline{A} \cdot B$

@FAKE_CBSE_X @RAJ_EDUNET

83. 

A	B	E
0	0	0
0	0	X
1	0	Y
1	1	1

In the truth table of the above circuit the value of X and Y are :

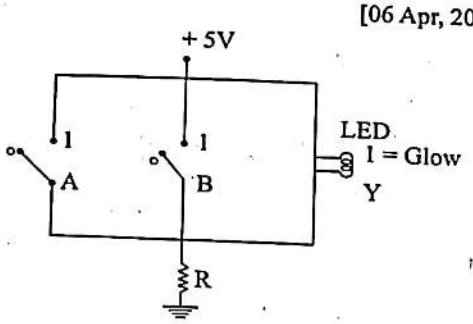
[09 April, 2024 (Shift-II)]

(a) 1, 1 (b) 1, 0

(c) 0, 1 (d) 0, 0

84. Name the logic gate equivalent to the diagram attached

[06 Apr, 2023 (Shift-I)]

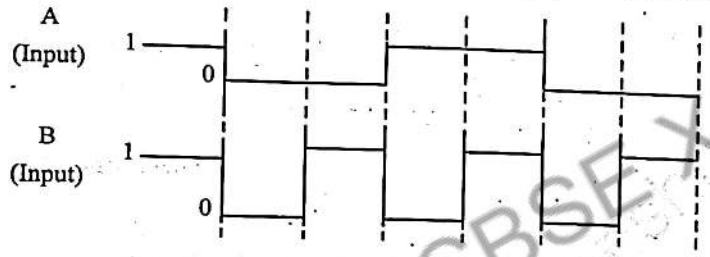


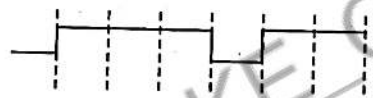
(a) OR (b) NOR

(c) NAND (d) AND

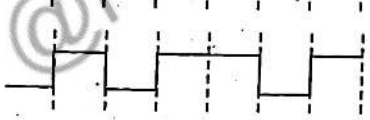
85. The output from a NAND gate having inputs A and B given below will be.

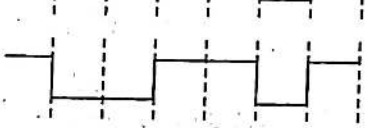
[13 Apr, 2023 (Shift-II)]



(a) 

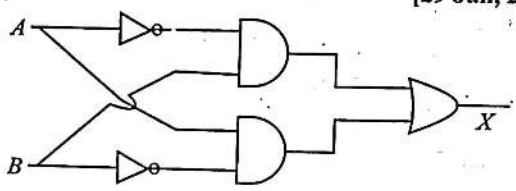
(b)

(c) 

(d) 

86. For the given logic gates combination, the correct truth table will be

[29 Jan, 2023 (Shift-II)]



(a)

A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

(b)

A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

(c)

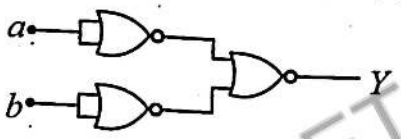
A	B	X
0	0	1
0	1	0
1	0	1
1	1	0

(d)

A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

87. The logic performed by the circuit shown in figure is equivalent to:

[11 Apr, 2023 (Shift-I)]

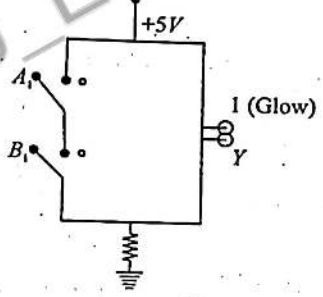


(a) AND (b) NAND

(c) OR (d) NOR

88. The logic gate equivalent to the given circuit diagram is:

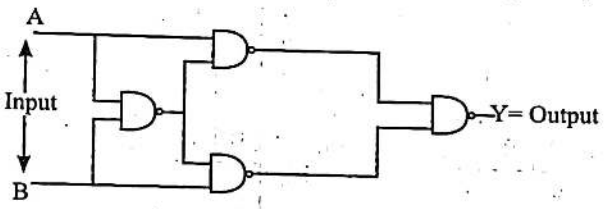
[24 Jan, 2023 (Shift-II)]



(a) OR (b) NAND

(c) NOR (d) AND

89. The output Y for the inputs A and B of circuit is given by



Truth table of the shown circuit is:

[30 Jan, 2023 (Shift-II)]

(a)

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

(b)

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

(c)

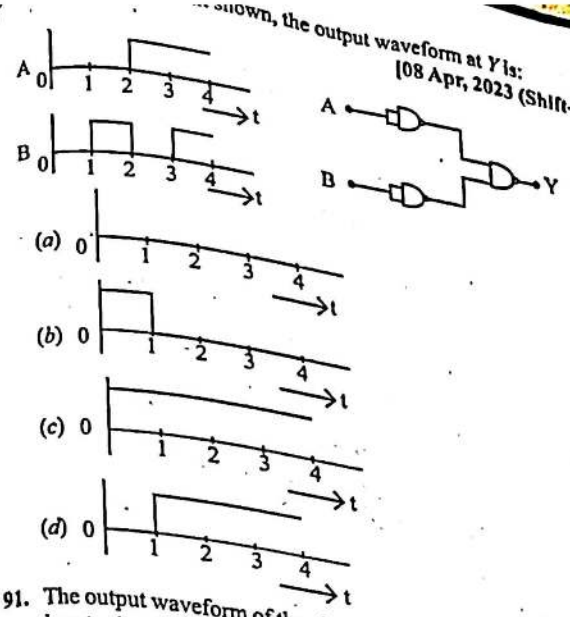
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

(d)

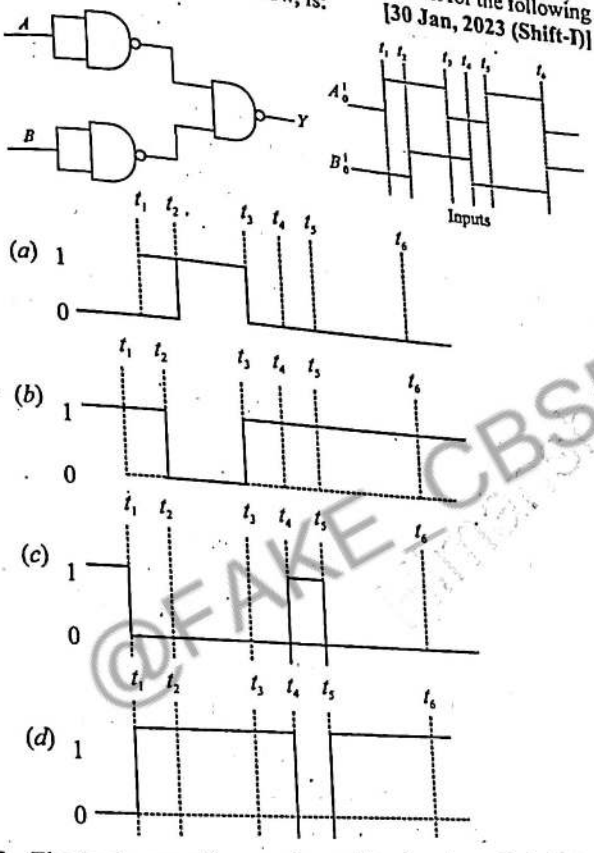
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

@FAKE_CBSE_X @RAJ_EDUNET

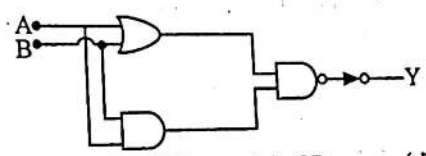
...shown, the output waveform at Y is:
[08 Apr, 2023 (Shift-I)]



91. The output waveform of the given logical circuit for the following inputs A and B as shown below, is:
[30 Jan, 2023 (Shift-I)]

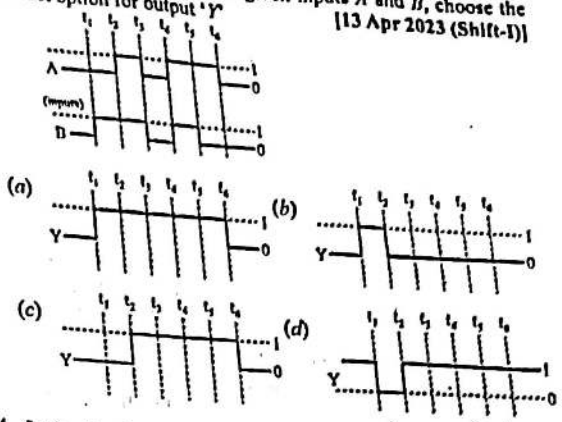


92. The logic operations performed by the given digital circuit is equivalent to:
[11 Apr, 2023 (Shift-II)]

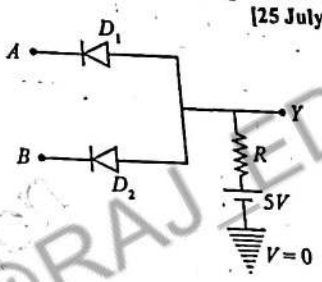


(a) AND (b) NOR (c) OR (d) NAND

93. For the following circuit and given inputs A and B, choose the correct option for output 'Y'
[13 Apr 2023 (Shift-I)]



94. In the circuit, the logical value of $A = 1$ or $B = 1$ when potential at A or B is 5 V and the logical value of $A = 0$ or $B = 0$ when potential at A or B is 0 V. The truth table of the given circuit will be:
[25 July, 2022 (Shift-I)]



(a)

A	B	Y
0	0	0
1	0	0
0	1	0
1	1	1

(b)

A	B	Y
0	0	0
1	0	1
0	1	1
1	1	1

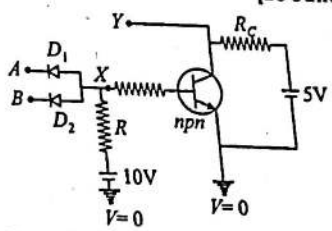
(c)

A	B	Y
0	0	0
1	0	0
0	1	0
1	1	0

(d)

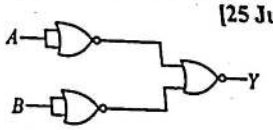
A	B	Y
0	0	1
1	0	1
0	1	1
1	1	0

95. In the following circuit, the correct relation between output (Y) and inputs A and B will be:
[28 June, 2022 (Shift-I)]



(a) $Y = AB$ (b) $Y = A + B$ (c) $Y = \overline{AB}$ (d) $Y = \overline{A + B}$

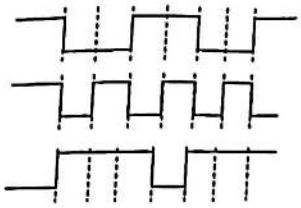
96. Identify the logic operation performed by the given circuit:
[25 June, 2022 (Shift-II)]



(a) AND gate (b) OR gate (c) NOR gate (d) NAND gate

@FAKE_CBSE_X_@RAJ_EDUNET

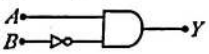
97. Identical the correct logic gate for the following output (Y) of two inputs A and B. **[27 June, 2022 (Shift-I)]**



(a)

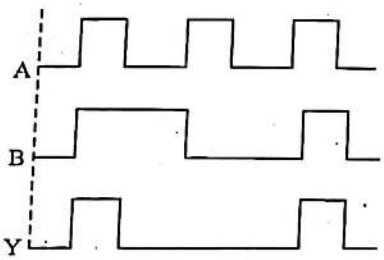
(b)

(c)

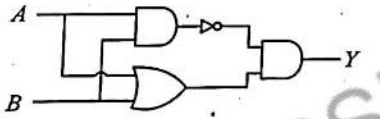
(d) 

98. A logic gate circuit has two inputs A and B and output Y. The voltage waveforms of A, B and Y are shown below. The logic gate circuit is: **[27 July, 2022 (Shift-I)]**

(a) AND gate (b) OR gate
(c) NOR gate (d) NAND gate

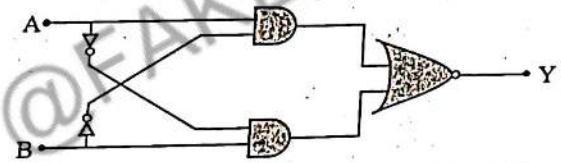


99. Which one of the following will be the output of the given circuit? **[17 Mar, 2021 (Shift-II)]**



(a) XOR Gate (b) NOR Gate
(c) NAND Gate (d) AND Gate

100. The truth table for the following, logic circuit is: **[25 Feb, 2021 (Shift-II)]**



(a)

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

(b)

A	B	Y
0	0	0
0	1	1
1	0	0
1	1	1

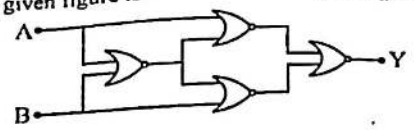
(c)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

(d)

A	B	Y
0	0	1
0	1	0
1	0	1
1	1	0

101. Four NOR gates are connected as shown in figure. The truth table for the given figure is: **[26 Aug, 2021 (Shift-II)]**



(a)

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

(b)

A	B	Y
0	0	1
0	1	0
1	0	1
1	1	0

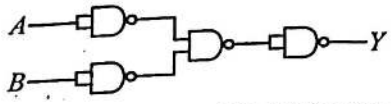
(c)

A	B	Y
0	0	0
0	1	1
1	0	0
1	1	1

(d)

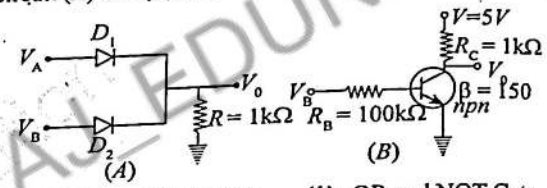
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

102. The following logic gate is equivalent to: **[16 Mar, 2021 (Shift-II)]**



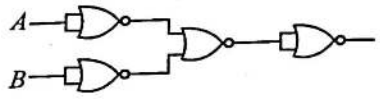
(a) NOR Gate (b) NAND Gate
(c) OR Gate (d) AND Gate

103. If V_A and V_B are the input voltages (either 5V or 0V) and V_0 is the output voltage then the two gates represented in the following circuit (A) and (B) are: **[31 Aug, 2021 (Shift-II)]**



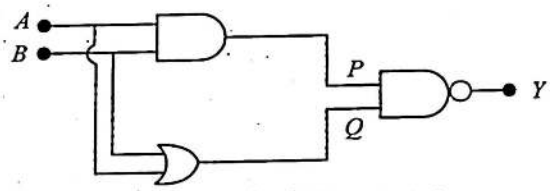
(a) NAND and NOR Gate (b) OR and NOT Gate
(c) AND and NOT Gate (d) AND and OR Gate

104. The output of the given combination gates represents **[17 Mar, 2021 (Shift-I)]**



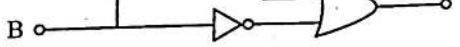
(a) AND Gate (b) NOR Gate
(c) NAND Gate (d) XOR Gate

105. In the following logic circuit the sequence of the inputs A, B are (0, 0), (0,1), (1, 0) and (1, 1). The output Y for this sequence will be: **[31 Aug, 2021 (Shift-I)]**



(a) 0, 1, 0, 1 (b) 1, 1, 1, 0
(c) 1, 0, 1, 0 (d) 0, 0, 1, 1

106. Find the truth table for the function Y of A and B represented in the following figure. **[27 July, 2021 (Shift-II)]**



@FAKE_CBSE_X_@RAJ_EDUNET

(a)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

(b)

A	B	Y
0	0	1
0	1	0
1	0	1
1	1	1

(c)

A	B	C
0	0	0
0	1	1
1	0	0
1	1	0

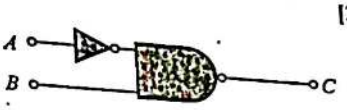
(d)

A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

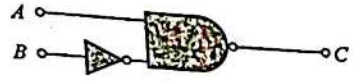
107.

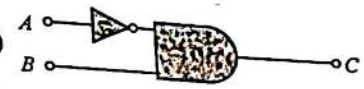
The logic circuit shown above is equivalent to:

[24 Feb, 2021 (Shift-II)]

(a)


(b)

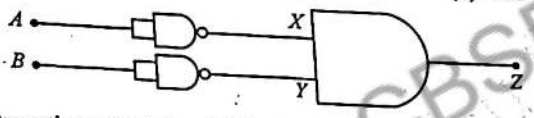
(c)


(d)


108. Identify the logic operation carried out by the given circuit :-

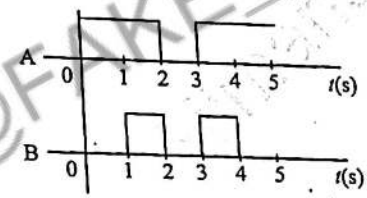
[26 Aug, 2021 (Shift-I)]

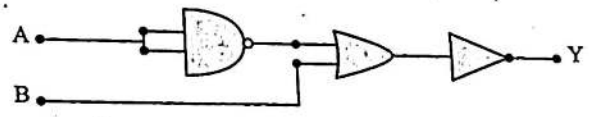
(a) NAND (b) NOR (c) AND (d) OR

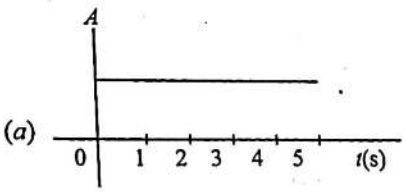


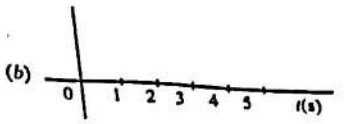
109. Draw the output signal Y in the given combination of gates.

[26 Feb, 2021 (Shift-II)]

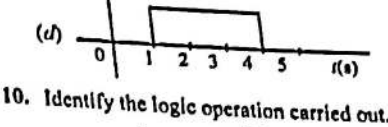




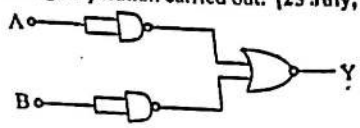
(a)


(b)


(c)

(d)


110. Identify the logic operation carried out. **[25 July, 2021 (Shift-I)]**



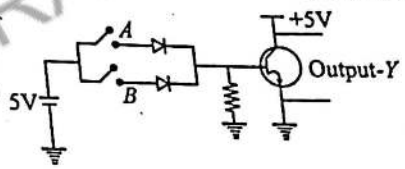
(a) OR (b) NOR (c) AND (d) NAND

111. In the logic circuit shown in the figure, if input A and B are 0 to 1 respectively, then output at Y would be 'x'.
The value of x is _____.

[16 Mar, 2021 (Shift-I)]

112. Boolean relation at the output stage-Y for the following circuit is

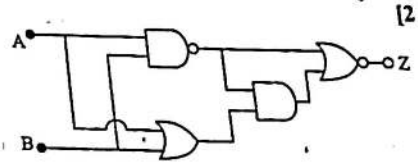
[8 Jan, 2020 (Shift-I)]



(a) $\overline{A}+\overline{B}$ (b) $\overline{A}.\overline{B}$ (c) $A.B$ (d) $A+B$

113. In the following, digital circuit, what will be the output at 'Z', when the input (A, B) are (1, 0), (0, 0) (1, 1), (0, 1)

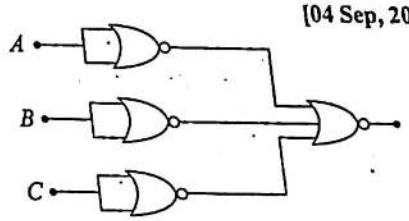
[2 Sep, 2020 (Shift-II)]



(a) 0, 1, 0, 0 (b) 1, 0, 1, 1
(c) 1, 1, 0, 1 (d) 0, 0, 1, 0

114. Identify the operation performed by the circuit given below:

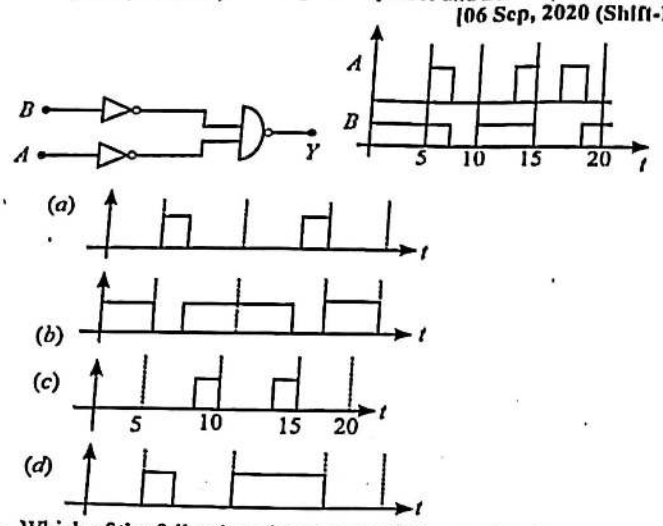
[04 Sep, 2020 (Shift-II)]



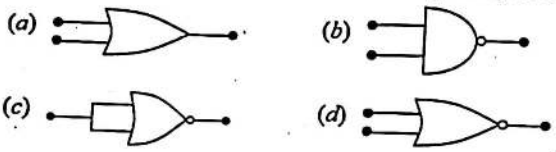
(a) AND (b) NOT (c) NAND (d) OR

@FAKE_CBSE_X @RAJ_EDUNET

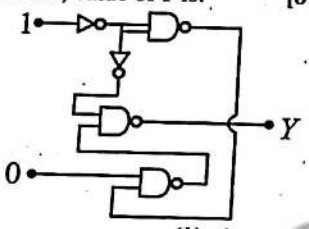
115. Identify the correct output signal Y in the given combination of gates (as shown) for the given inputs A and B.
[06 Sep, 2020 (Shift-I)]



116. Which of the following given a reversible operation?
[7 Jan, 2020 (Shift-I)]

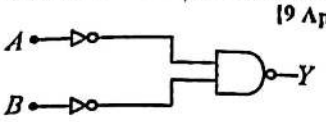


117. In the given circuit, value of Y is: **[8 Jan, 2020 (Shift-II)]**



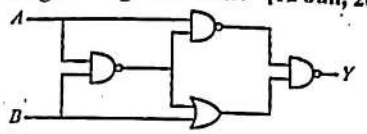
(a) 0 (b) 1
(c) toggles between 0 and 1 (d) will not execute

118. The logic gate equivalent to the given logic circuit is
[9 Apr, 2019 (Shift-II)]



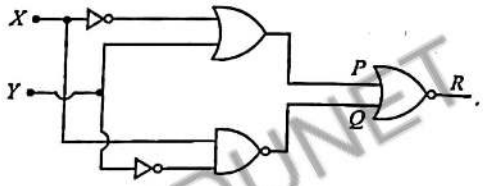
(a) OR (b) AND (c) NOR (d) NAND

119. The output of the given logic circuit is: **[12 Jan, 2019 (Shift-I)]**

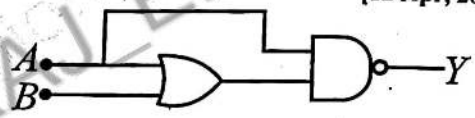


(a) $A\bar{B}+\bar{A}B$ (b) $AB+\overline{A\bar{B}}$
(c) $A\bar{B}$ (d) $\bar{A}B$

120. To get output '1' at R, for the given logic gate circuit the input values must be:
[10 Jan, 2019 (Shift-I)]
(a) $X=0, Y=1$ (b) $X=1, Y=1$
(c) $X=1, Y=0$ (d) $X=0, Y=0$



121. The truth table for the circuit given in the figure is
[12 Apr, 2019 (Shift-I)]



(a)

A	B	Y
0	0	1
0	1	1
1	0	0
1	1	0

(b)

A	B	Y
0	0	0
0	1	0
1	0	1
1	1	1

(c)

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

(d)

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	1

@FAKE_CBSE_X@RAJ_EDUNET

ANSWER KEY

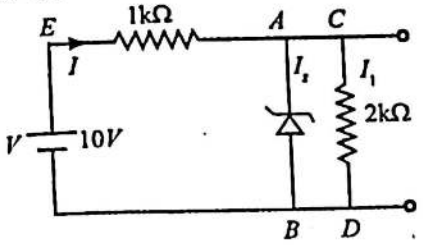
JEE-Main

1. (d)	2. (b)	3. (c)	4. (a)	5. (Bonus)	6. (a)	7. (3)	8. [2]	9. (c)	10. [5]
11. (c)	12. (c)	13. (d)	14. (a)	15. (c)	16. (c)	17. (d)	18. (c)	19. (b)	20. (a)
21. (c)	22. (c)	23. (c)	24. [5]	25. (d)	26. (b)	27. (b)	28. (d)	29. (b)	30. [2]
31. [14]	32. [25]	33. [480]	34. [3.1]	35. [4]	36. [9]	37. [1]	38. (b)	39. (d)	40. (d)
41. (c)	42. (d)	43. (c)	44. (b)	45. (d)	46. (c)	47. (b)	48. [25]	49. [20]	50. [5]
51. [25]	52. [20]	53. [9]	54. [500]	55. [5]	56. [192]	57. [120]	58. (c)	59. (a)	60. (d)
61. (c)	62. (a)	63. (c)	64. (a)	65. (b)	66. [12]	67. [40]	68. (b)	69. (d)	70. (b)
71. (c)	72. (b)	73. (a)	74. (b)	75. (b)	76. (c)	77. (c)	78. (b)	79. (b)	80. (b)
81. (2)	82. (c)	83. (a)	84. (b)	85. (a)	86. (b)	87. (a)	88. (b)	89. (d)	90. (d)
91. (d)	92. (a)	93. (d)	94. (a)	95. (c)	96. (a)	97. (b)	98. (a)	99. (a)	100. (a)
101. (a)	102. (a)	103. (b)	104. (c)	105. (b)	106. (b)	107. (d)	108. (b)	109. (c)	110. (c)
111. [0]	112. (b)	113. (d)	114. (a)	115. (*)	116. (c)	117. (a)	118. (a)	119. (c)	120. (c)
121. (a)									

EXPLANATIONS

1. (*d*) For forward biasing.
P end should be at higher potential

2. (*b*) Given that



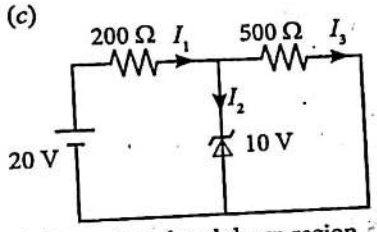
$V_Z = 3$ V
Let potential at $B = 0$ V
Potential at $E(VE) = 10$ V
$V_C = V_A = 3$ V
$I_Z + I_1 = I$
$I = V/R$,

$$I = \frac{10-3}{1000} = \frac{7}{1000} A$$

$$I_1 = \frac{3}{2000} A$$

Therefore $I_z = \frac{7-1.5}{1000} = 5.5$ mA

3. (*c*)



Zener is in breakdown region.

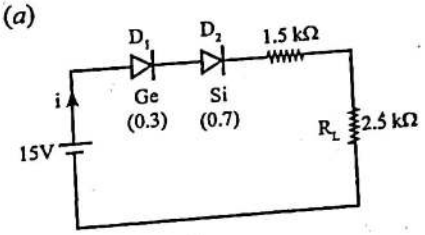
$$I_3 = \frac{10}{500} = \frac{1}{50}$$

$$I_1 = \frac{10}{200} = \frac{1}{20}$$

By kirchhoff's junction law,
$I_2 = I_1 - I_3$

$$I_2 = \left(\frac{1}{20} - \frac{1}{50}\right) = \left(\frac{3}{100}\right) = 30 \text{ mA}$$

4. (*a*)



$$i = \frac{14}{4} = 3.5 \text{ mA}$$

voltage across load resistance (R_L) is

$V_L = iR_L = 3.5 \times 2.5$ volt
$= 8.75$volt

5. (Bonus)
Potential difference across R_s
$V_1 = 8 - 5 = 3$V
Current through the load resistor

$$I = \frac{5}{1\times10^3} = 5 \text{ mA}$$

$$I_{z\max.} = \frac{10}{5} = 2 \text{ mA} \ \& \ I_{z\min.} = 0$$

$$\therefore I_{s\max.} = 5 + 2 = 7 \text{ mA}$$

And $R_{s\,min} = \frac{V_1}{I_{s\,max}} = \frac{3}{7} k\Omega$

Similarly, $I_{s\,min.} = 5$mA

And $R_{s\max} = \frac{V_1}{I_{s\,min.}} = \frac{3}{5} k\Omega$

$$\therefore \frac{3}{7} k\Omega < R_s < \frac{3}{5} k\Omega$$

6. (*a*) Band gap of photodiode,

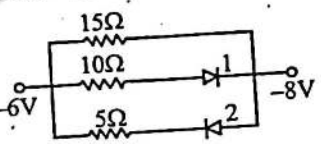
$$E_g = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^8}{660\times10^{-9}} J$$

$$= \frac{6.6\times10^{-34}\times3\times10^8}{660\times10^{-9}\times1.6\times10^{-19}} eV$$

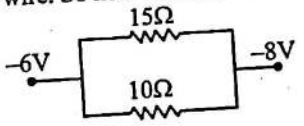
$$= \frac{15}{8} eV$$

$\therefore x = 15$

7. (3)



Diode 1 is in forward bias
So it will behave like conducting wire. So new circuit will be



$$R_{eq} = \frac{15\times10}{15+10} = \frac{15\times10}{25} = 6\Omega$$

Diode 2 is in reverse bias
So current will not flow in branch of 2nd diode, So we can assume it to be broken wire.

8. [2] To calculate dynamic resistance Diode should be in forward biased

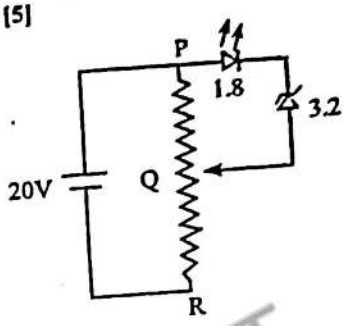
9. (*c*) Energy $= \frac{hc}{\lambda}$;

$$E = \frac{1240}{\lambda(nm)} eV$$

$$\Rightarrow \lambda(\text{nm}) = \frac{1242}{E}$$

$$\lambda = \frac{1242}{6} = 207 \text{ nm}$$

10. [5]



Voltage across diodes should be
$1.8 + 3.2 = 5$V

$$\Rightarrow \frac{20V}{20\text{cm}} \times l_{min} = 5V$$

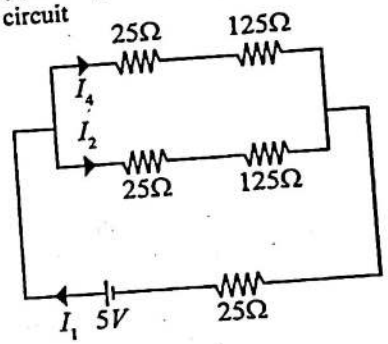
$l_{min} = 5$ cm

11. (*c*) Wavelength of emitted light,

$$\lambda = \frac{1240}{1.42} = 875 \text{ nm (Approx)}$$

12. (*c*) Zener diode current voltage characteristic.

13. (*d*) As D_2 is reverse biased. So reduce circuit



$$R_{Total} = \frac{150\times150}{300} + 25 = 100\Omega$$

$$I_1 = \frac{5}{100} = 0.05 A$$

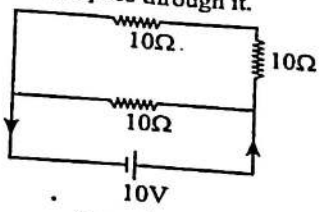
Using KCL $I_1 = I_2 + I_4$

$$I_2 = I_4 = \frac{0.05}{2} = 0.025 A$$

$$\frac{I_1}{I_2} = \frac{0.05}{0.025} = 2$$

@FAKE_CBSE_X @RAJ_EDUNET

14. (*a*) In the circuit diode, D_1 and D_2 are forward biased and D_2 is reverse biased therefore D_2 Would not allow to the current pass through it.

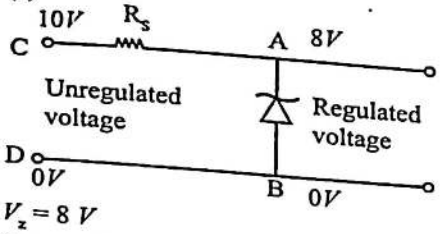


$$R_{eq}=\frac{(10+10)\times10}{(10+10)+10}=\frac{20}{3}\Omega,\ I=\frac{V}{R_{eq}}$$

$$\therefore I=\frac{10}{20/3}=\frac{3}{2}A=1.5A$$

15. (*c*) Based on theory.

16. (*c*)



$V_z=8\ V$

Current flow in zener diode,

$$I=\frac{P}{V_z}=\frac{1.6W}{8V}=0.2A$$

$$\therefore R_s=\frac{V_C-V_A}{i}=\frac{(10-8)V}{0.2A}=10\ \Omega$$

[**Note** : A zener diode can regulate only if input voltage is ≥ zener breakdown voltage the range of input voltage should be 8 to 10 *V* so that output voltage remains constant = 8 V]

17. (*d*) When a *P-N* junction diode is formed an electric field is developed from *N*-side to *P*-side due to which barrier potential is created & majority charge carrier can not flow through the junction due to barrier potential so current is zero unless we apply forward bias voltage.

18. (*c*) As temperature is increased, more electrons are excited to the conduction band and hence conductivity increases, therefore resistance decreases.

19. (*b*) Photodiodes are operated in reverse biasing, as fractional change in current due to light is more easily measurable in reverse biasing.

20. (*a*) Works as voltage regulator in reverse bias and as simple p-n junction in forward bias.

21. (*c*) Diffusion current takes place from *p*-side to *n*-side when p-n junction is forward bias.

22. (*c*) Theory based

A Photodiode is operated in reverse bias condition.

For a P-N junction diode current in forward bias (for $V \geq V_{0}$) is always greater than the current in reverse bias (for $V \leq V_{z}$)

Hence, Assertion is false but Reason is true

23. (*c*) LED works when it is forward biased.

24. [5] $I_L=\frac{V}{R_L}=\frac{5}{1000}=5mA$

25. (*d*)

26. (*b*) In forward bias diode conducts
In reverse bias it does not conducts.

27. (*b*) $R=\frac{\Delta V}{\Delta i}$

$$\frac{R_1}{R_2}=\frac{\Delta v_1}{\Delta v_2}\frac{\Delta i_2}{\Delta i_1}=\frac{0.1}{0.2}\times\frac{50}{2}=5$$

28. (*d*) In + ve half cycle

$D_1 \rightarrow F.B.; D_2 \rightarrow R.B.$

0 – 0.6 V

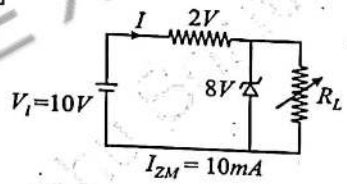
V_{out} same as V_{in}

In –ve half cycle

$D_2 \rightarrow F.B.; D_1 \rightarrow R.B.$

29. (*b*) *I-V* characteristic graph is plotted in 4th quadrant for solar cell that is, where current is negative, because current is supplied by the solar cell and not drawn by it.

30. [2]



$$I=\frac{2}{100}=20\ mA$$

$$V_L=I_LR_L \Rightarrow 8=10\times10^{-3}\times R_{L_{max}}$$

$$\frac{4}{5}\times10^3=R_{L_{max}}$$

$$I=I_Z+I_L$$

$I_L=10\ mA$.

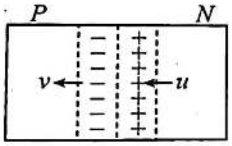
If $I_Z=0$

$$\therefore I_{L_{max}}=20mA \Rightarrow V_L=I_{L_{max}}\times R_{L_{min}}$$

$$\frac{8}{20}\times10^3=R_{L_{min}}$$

$$400=R_{L_{max}} \Rightarrow \frac{R_{L_{max}}}{R_{L_{min}}}=\frac{800}{400}=2$$

31. [14]



Work done by Electric field = $K_f - K_i$

$$\frac{1}{2}mv^2-\frac{1}{2}mu^2=-1.6\times10^{-19}\times0.4$$

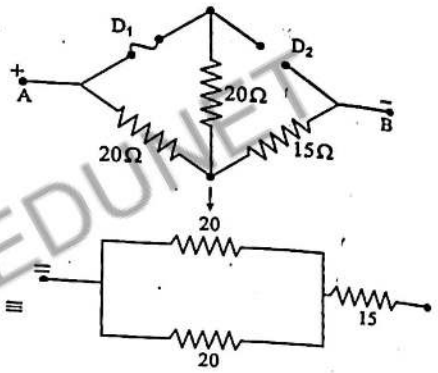
$$\frac{1}{2}\times9\times10^{-31}(v^2-u^2)=-0.64\times10^{-19}$$

$$u^2-v^2=\frac{2\times0.64\times10^{12}}{9}$$

$$v^2=\left(36-\frac{128}{9}\right)\times10^{10}$$

$$v=\frac{14}{3}\times10^5\ m/s\ ,\ x=14.$$

32. [25]



Here diode-D_1 is forward biased and diode-D_2 is reversed biased, Equivalent resistance between *A* & *B*.

$$R_{eq}=\frac{20\times20}{20+20}+15=25\ \Omega$$

33. [480]

$$V-I_MR-V_z=0$$

$$\Rightarrow 20-I_MR-8=0 \Rightarrow I_MR=12$$

$$\Rightarrow 25\times10^{-3}\times R=12$$

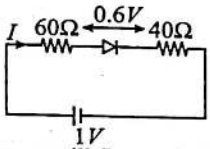
$$\Rightarrow R=\frac{12}{25\times10^{-3}}=480\Omega$$

34. [3.1]

Formula of energy gap.

$$E_g=\frac{hc}{l}=\frac{1242}{l\ (nm)}=\frac{1242}{400}=3.105$$

35. [4]



Current will flow only through diode-D_1 as it is forward biased

Applying Kirchoff's law

$$1-I(60)-0.6-I(40)=0$$

$$\frac{0.4}{100}=I$$

$I=4$mA

36. [9] Current in the load,

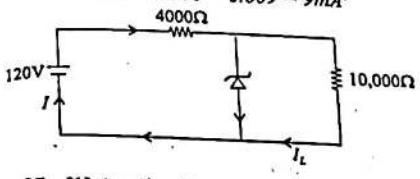
$$I_L=\frac{60}{10,000}=0.006A$$

@NEET_OBSE X @NEET_EDUNET

$I = \frac{120-60}{4000} = 0.015A$

Thus, maximum zener current, $I_z = I - I_L$

$= 0.015 - 0.006 = 0.009 = 9mA$

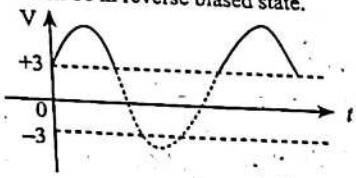


37. [1] As, $E_d = V_B$

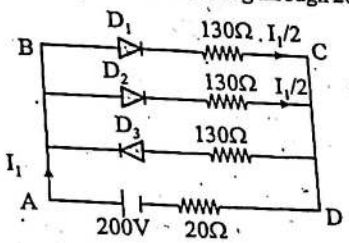
$\therefore E = \frac{V_B}{d} = \frac{0.6}{6\times10^{-6}} = 1\times10^5\ N/C$

38. (*b*) When $V_i > 3$ volt, $V_R > 0$, because diode will be in forward biased state.

When $V_i \le 3$ volt, $V_R = 0$, because diode will be in reverse biased state.



39. (*d*) Diode 1 and 2 are in forward bias with $R = 30\Omega$ and D_3 is reverse bias with $R =$ infinite. I_1 current is flowing through 20Ω



Αππλψινγ κςΛ

$\left(\frac{I_1}{2}\right)\times30 - \left(\frac{I_1}{2}\right)\times130 - I_1\times20 + 200 = 0$

$\Rightarrow 200 - 100I_1 = 0$

$\Rightarrow I_1 = 2$

40. (*d*) Zener break down occurs in $p-n$ junction having both *p and n* layer heavily doped and have narrow depletion layer.

41. (*c*) Fermi level of p-type semiconductors will go downward.

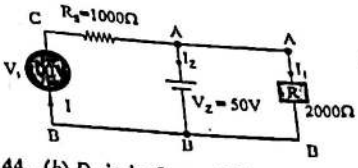
42. (*d*) Minimum required energy,

$E_{min} = \frac{hc}{\lambda_{max}}$

$E_{min} = \frac{1242eV-nm}{621nm} = 2eV$

43. (*c*) $I_2 = \frac{V_i - V_Z}{R_S} - \frac{V_Z}{R}$

$= \frac{100-50}{1000} - \frac{50}{2000} = 25mA$



44. (*b*) D_1 is in forward bias and D_2 is in reverse bias.

Voltage drop accross silicon diode, $V_i = 0.7$

Current supplied by the battery, $I = \frac{5-0.7}{10} = 0.43$ A

45. (*d*) Wavelength of emitted light,

$\lambda = \frac{hc}{E} = \frac{6.63\times10^{-34}\times3\times10^8}{1.9\times1.6\times10^{-19}} = 654nm$

(Red)

46. (*c*)

47. (*b*) Pentavalent materials have more electrons and so electron density increase. But overall semiconductor is neutral

48. [25] Since potential difference across 2kΩ is 5V, therefore current through it,

$i = \frac{5}{2\times10^3} = 25\times10^{-4}\ A$

49. [20] D_1 is forward biased & D_2 is reverse biased.

The current through the 120Ω resistance

$I = \frac{6}{120+130+50} = \frac{6}{300}$

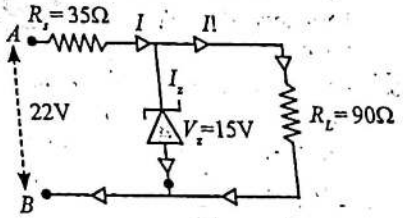
$= 2\times10^{-2}\ A = 20\times10^{-3}\ A = 20mA$

50. [5] $I_z = I - I_{RL} = \left(\frac{22-15}{35}\right) - \frac{15}{90} = \frac{1}{30}$A

Power dissipated across zener diode, $= V_z I_z$

$= \frac{1}{30}\times15 = 5\times10^{-1}W$

Hence, the value of x is 5.



51. [25] According to the graph as shown in the question,

$R = \frac{\Delta V}{\Delta I} = \frac{0.75-0.70}{(5-3)\times10^{-3}}$

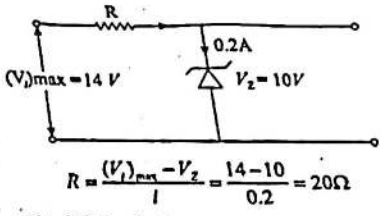
$= \frac{0.05\times1000}{2} = 25\Omega$

52. [20] We have given, $(V_i)_{max} = 14V$,

$V_Z = 10V$

Maximum current through zener diode,

$i = \frac{2}{10} = 0.2$A

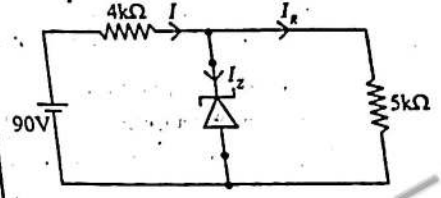


$R = \frac{(V_i)_{max} - V_z}{I} = \frac{14-10}{0.2} = 20\Omega$

53. [9] $I_z = I - I_R$

$I_z = \frac{90-30}{4000} - \frac{30}{5000}$

$I_z = 15\times10^{-3} - 6\times10^{-3} = 9mA$



54. [500] If $I_{z(max)} = 90$mA then current in R should be greater than 90mA.

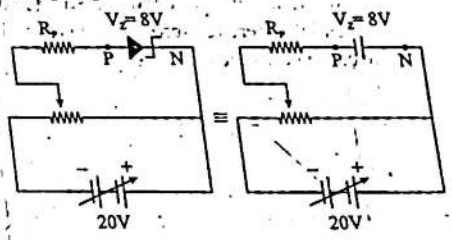
$R = \frac{V_i - V_z}{I_{z(max)}} = \frac{50-5}{90\times10^{-3}}$, $R = 500\Omega$

55. [5] $n^2 = n_h \cdot n_e \Rightarrow n_e = \frac{n^2}{n_h}$

$n_e = \frac{1.5\times1.5\times10^{32}}{4.5\times10^{22}} = \frac{10^{10}}{2} = 0.5\times10^{10}$

$= 5\times10^9\ /m^3$

56. [192]

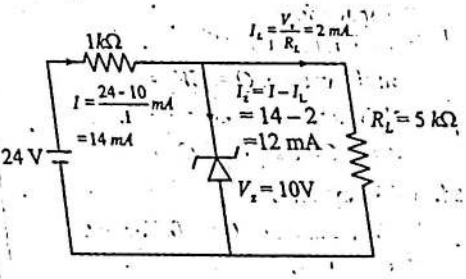


$P_z = V_z I_z \Rightarrow 0.5 = 8I_z \Rightarrow I_z = \frac{1}{16}$Amp

$I_z = \frac{20-V_z}{R_p} \Rightarrow \frac{1}{16} = \frac{20-8}{R_p}$

$\Rightarrow R_p = 16\times12 = 192\Omega$

57. [120]



@EAKE_CBSE_X@RAJ_EDUNET

Power across zener diode,
$P_z = V_z I_z = 10 \times 12 = 120$ mW

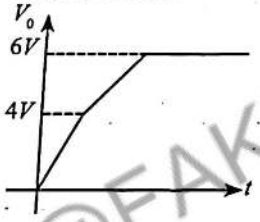
58. (c) A V-O-M multimeter measure voltage, resistance, and current. 9t does not show deflection when it connects with capacitor.

59. (a) As there are two zener diodes in reverse polarity if one is in forward bias the other will be in revere bias above 6V the reverse bias will too be in conduction mode. Therefore when voltage is more than 6V the output will be constant, and when it is less than 6V it will follow the input voltage.

60. (d) Both diodes are in reverse direction, so no current will through *it*. All the resistor are in series.
So, $R_{eq} = 5 + 10 + 5 + 10 = 30\ \Omega$
The current i in the network,
$$I = \frac{9}{30} = \frac{3}{10} A = 0.3A$$

61. (c) For photodiode to detect $\frac{hc}{\lambda}$ > band gap energy
$$\Rightarrow \text{Band gap energy} = \frac{hc}{\lambda_{max}}$$
$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{400\times10^{-9}} = 5\times10^{-19} J$$
$= 3.1$ eV

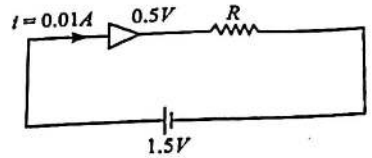
62. (a) As input voltage varies between 0 – 4V, zener diode does not reach breakdown vantage. Hence $V_0 = V_i$
As input voltage varies between 4 – 6 V, zener diode with 4V will break down and potential difference across this zener will become constant



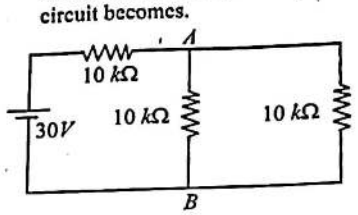
As input voltage raises beyond 6 V. Both zener diodes break down, output potential is measured across 6 V diode. Hence out put potential remains 6V

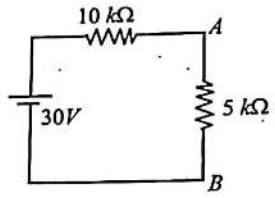
63. (c) Diode is reversed biased so, no current will flow through it and charge on the capacitor,
$Q_A = CV_0 = CV$
Initial charge, $Q = CV_0 = CV$
Now, $q = Qe^{-t/RC}$, at $t = CR$
$\Rightarrow q = CV/e$ so, $Q_B = CV/e$

64. (a) Using *KVL*
$65.....5 - 0.5 - 0.01\,R = 0$
$\Rightarrow R = 100\Omega$



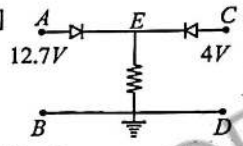
65. (b) Diode in forward bias act as a short circuit wire. Hence, the equivalent circuit becomes.





So, $V_{ab} = \frac{30}{5+10} \times 5 = 10V.$

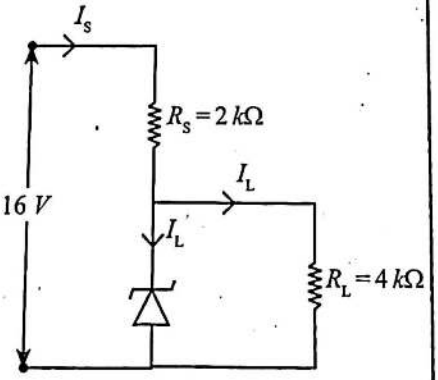
66. [12]



Let $V_B = 0$
Right diode is reversed biased and left diode is forward biased
$\therefore V_E = 12.7 - 0.7 = 12$ Volt

67. [40]
$$i = \frac{(12-8)}{(200+200)} A = \frac{4}{400} = 10^{-2} A$$
Power loss in each diode = (4) (10^{-2}) W
= 40 mW

68. (b) Current through zener diode is maximum
$I_z = I_{R_S} - I_{R_L}$
$$I_z = \frac{(16-6)}{2000} - \frac{6}{4000} \Rightarrow I_z = 3.5\ mA$$



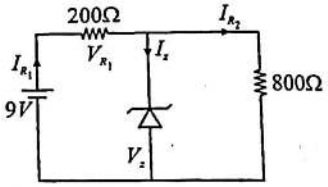
69. (d) Initially Ge and Si one both forward biased, so current will effectively pass through Ge diode.
$\therefore (V_o)_1 = 12 - 0.3 = 11.7$ V
and if Ge is reversed then current will flow through Si diode.
$(V_o)_2 = 12 - 0.7 = 11.3$ V
So, $|\Delta V_o| = |(V_o)_2 - (V_o)_1|$
$|\Delta V_o| = |11.3 - 11.7| = 0.4$ V

70. (b) $I = \frac{6}{300} = 0.02A$ (D_2 is in reverse bias)

71. (c) Hence $j = \sigma\varepsilon = neV_d$
$$\sigma = \frac{neV_d}{E} = ne\mu \quad [\text{H is mobility}]$$
$$\frac{1}{\sigma} = \rho = \frac{1}{n_e e \mu_e} \quad [\rho \text{ is reistivity}]$$
$$\rho = \frac{1}{10^{19}\times1.6\times10^{-19}\times1.6} = 0.4\Omega - m$$

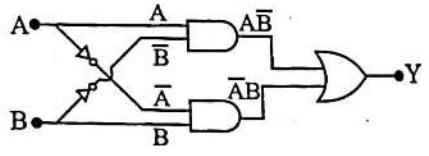
72. (b) At $V_B = 8$V
$$i_L = \frac{6\times10^{-3}}{4} = 1.5\times10^{-3} A$$
$$i_R = \frac{8-6\times10^{-3}}{1} = 2\times10^{-3} A$$
$\therefore i_{\text{zener diode}} = i_R - i_{\text{load}} = 0.5 \times 10^{-3}$ A
At $V_B = 16$ V
$i_L = 1.5 \times 10^{-3}$A
$$i_R = \frac{(16-6)\times10^{-3}}{1} = 10\times10^{-3} A$$
$\therefore i_{\text{zener diode}} = i_R - i_L = 8.5 \times 10^{-3}$ A

73. (a) $V_{R_1} = 9 - 5.6 = 3.4$ V
$$\therefore I_{R_1} = \frac{V_{R_1}}{R} = \frac{3.4}{200} = 17 \text{ mA}$$



$I_z = I_{R_1} - I_{R_2}$
$$I_z = \left(17 - \frac{5.6}{800}\right) \text{mA}$$
$I_z = (17 - 7)$ mA = 10 mA

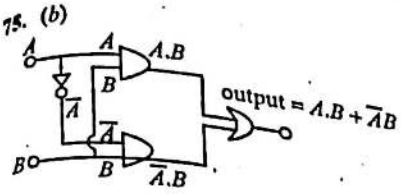
74. (b)



$Y = A.\bar{B} + \bar{A}.B$
It represents XOR GATE.
Hence option (b) Truth-Table will satisfy XOR GATE output.

@FAKE_CBSE_@RAJ_EDUNET

75. (b)



$Y = A.B + \bar{A}.B = (A + \bar{A}).B$

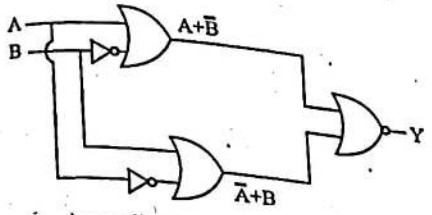
$Y = 1.B$

$Y = B$

76. (c) $Y = \overline{\bar{A} \cdot \bar{B}} = \bar{\bar{A}} + \bar{\bar{B}} = A + B$

Above equation represents De-Morgan's law

77. (c)



According to the logic gates diagram,

A	$\bar{A}$
0	1
1	0

B	$\bar{B}$
0	1
1	0

$Y = \overline{(A + \bar{B}) + (\bar{A} + B)} = \overline{(1 + 1)} = 0$

78. (b) Output for the given logic gate

$Y = \overline{\bar{A} \cdot \bar{B}}$

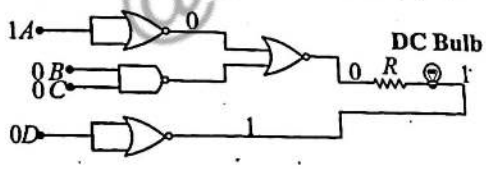
By applying De-Morgan Law

Now, $Y = \overline{\overline{A + B}} \Rightarrow Y = A + B$

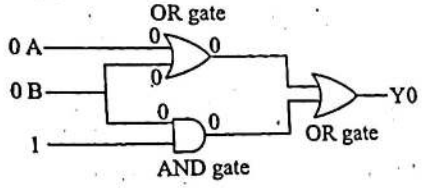
OR gate gives this output

79. (b) When bulb have potential drop on it, the bulb will glow.

One end of bulb must be at high (1) and other must be at low (0).



80. (b)

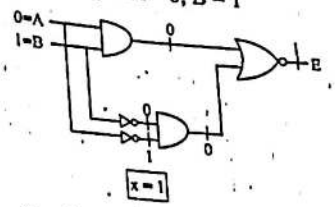


81. (2) Apply basic NOT gate AND and OR gate rule.

82. (c) By truth table

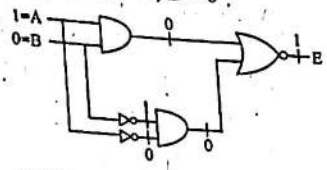
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	0

83. (a) For, input A = 0, B = 1



x = 1

For, input A = 1, B = 0



84. (b) When either or both of A & B is closed we get current bypass from switch

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Hence it is "NOR" gate

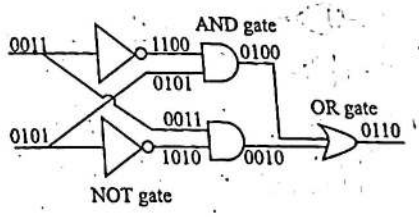
85. (a) For NAND gate, $Y = \overline{A \cdot B}$

On the basis of given input A and B the truth table is

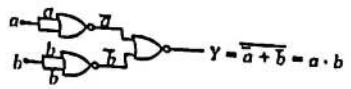
A	B	$Y = \overline{A \cdot B}$
1	1	0
0	0	1
0	1	1
1	0	1
1	1	0
0	0	1
0	1	1

So the correct answer is Option (a).

86. (b)



87. (a)



$Y = \overline{\bar{a} + \bar{b}} = a \cdot b$ (using Demorgon theorem)

This will be AND gate.

88. (b)

A_1	B_1	Y
0	0	1
0	1	1
1	0	1
1	1	0

As the output $Y = \overline{A_1 \odot B_1}$

$\Rightarrow$ *NAND* gate

89. (d) Given circuit act like a XOR.

90. (d) $Y = \overline{\bar{A} \cdot \bar{B}} = \bar{\bar{A}} + \bar{\bar{B}} = A + B$

So truth table,

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

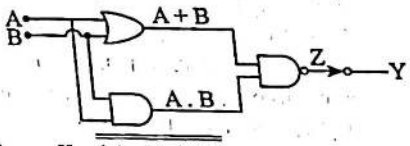
According to value of output Y, option d will be correct output waveform.

91. (d) $\left(\overline{A \cdot A}\right) = \bar{A}$

$\overline{B \cdot B} = \bar{B}$

$\left(\overline{\bar{A} \cdot \bar{B}}\right) = A + B$, OR Gate

92. (a)

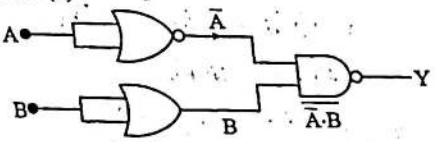


$Y = \overline{(A + B).(AB)}$

$= (A + B).\overline{AB} = AB + \overline{AB} = AB$

$\therefore$ It is an AND Gate

93. (d)



$Y = \overline{\bar{A} \cdot B} = A + \bar{B}$

94. (a) The given circuit is equiralent to AND gate

So truth table is

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

@FAKE_CBSE_X@RAJ_EDUNET

95. (c) This is NAND gate

A	B	Y
0	0	1
1	0	1
0	1	1
1	1	0

96. (a) $Y = (\overline{A+A}) + (\overline{B+B})$

$Y = \overline{A} + \overline{B}$ (D'Morgan Law) $Y = \overline{AB} = AB$

97. (b)

A	B	Y
1	1	0
0	0	1
0	1	1
1	0	1
1	1	0
0	0	1
0	1	11
1	0	1

NAND Gate

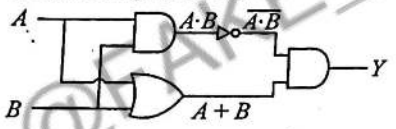
$Y = \overline{A.B}$

98. (a)

A	B	Y
0	0	0
1	1	1
0	1	0
1	0	0

According to the truth table the logic is AND gate.

99. (a) The result of a XOR gate is high (1) just when precisely one of its bits of inputs is high (1). In the event that both of a XOR gate's bits of inputs are low (0), or then again on the off chance that both of its bits of inputs are high (1), the result of the XOR gate is low.



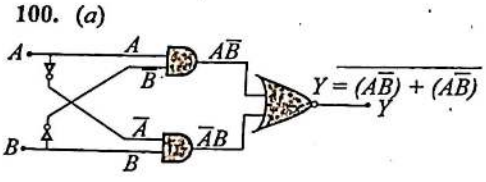
$y = (\overline{A \cdot B}) \cdot (A+B) = (\overline{A}+\overline{B}) \cdot (A+B)$

$= \overline{A}A + \overline{A}B + A\overline{B} + \overline{B}B$

$= 0 + \overline{A}B + A\overline{B} + 0$, $y = \overline{A}B + A\overline{B}$

Which is X O R gate

100. (a)



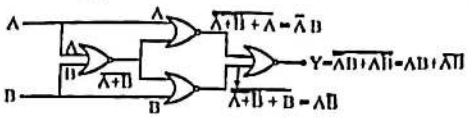
$Y = \overline{(A\overline{B}) + (\overline{A}B)} = \overline{(A\overline{B})}\,\overline{(\overline{A}B)}$

$Y = (\overline{A}+\overline{B}) + (\overline{\overline{A}+\overline{B}})$

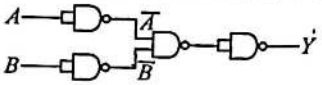
$= \left((\overline{A}+B)\right)\left((A+\overline{B})\right)$

$= AB + \overline{A}\overline{B}$

101. (a)



102. (a) The NOR gate is a computerized rationale door that carries out sensible NOR- it acts as per reality table to one side. A HIGH result (1) results if both the contributions to the entryway are LOW (0); in the event that one or both information is HIGH (1), a LOW result (0) results. NOR is the consequence of the nullification of the OR administrator.



Output of first NAND gate with input

$= \overline{A \cdot A} = \overline{A} + \overline{A} = \overline{A}$

Similarly, Output of first NAND gate with input B

$= \overline{B}$, $Y_1 = \overline{\overline{A} \cdot \overline{B}} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$

$Y = \overline{(A+B) \cdot (A+B)}$

$= \overline{(A+B)} + \overline{(A+B)} = \overline{(A+B)}$

So, given logic gates circuit is a NOR gate.

103. (b) Truth table for 1st circuit

A	B	V_0
0	0	0
0	1	1
1	0	1
1	1	1

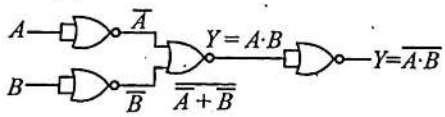
Thus circuit is *OR Gate*.

For 2nd circuit $V_B = 5V$, $A = 1$

$V_B = 0V$, $A = 0$ and when $A = 0$, $V_0 = 1$

$A = 1$, $V_0 = 0$ [$\therefore$ circuit is NOT gate]

104. (c)



105. (b) We have given the sequence of the inputs A and B

(0, 0); (0, 1); (1, 0); (1, 1).

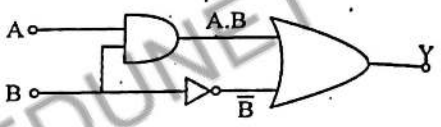
Thus, the output y is (1, 1, 1, 0)

0	0	0	0	1
0	1	0	1	1
1	0	0	1	1
1	1	1	1	0

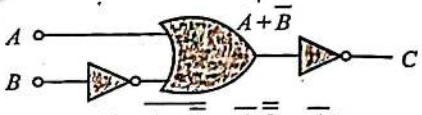
106. (b) Here $Y = A \times B + \overline{B}$

So the output will be as given in the below table

A	B	Y
0	0	1
0	1	0
1	0	1
1	1	1



107. (d)



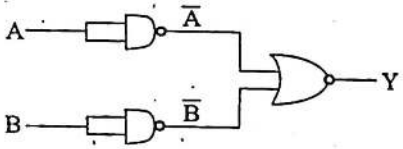
$C = \overline{A + \overline{B}} = \overline{A}.\overline{\overline{B}} = \overline{A}B$

108. (b)

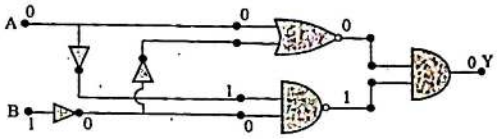
A	B	X	Y	Z
1	1	0	0	0
1	0	0	1	0
0	1	1	0	0
0	0	1	1	1

109. (c) $y = \overline{\overline{A} + \overline{B}} = A \cdot B$

110. (c) $Y = \overline{\overline{A} + \overline{B}} = \overline{A}.\overline{B} = A.B$



111. [0]



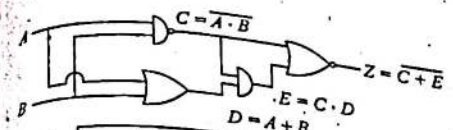
112. (b) First part of figure shown is OR gate and second part of figure shown is NOT gate.

@RAKE_CBSE_K@RAJ_EDUNET

So, Y_P = OR + NOT = NOR gate

$Y = \overline{A+B} = \overline{A}.\overline{B}$

113. (*d*)



A	B	Z
1	0	0
0	0	0
1	1	0
0	1	1
		0

114. (*a*) The output of the circuit is

$y = \overline{\overline{A}+\overline{B}} = \overline{\overline{A}}.\overline{\overline{B}}$

$y = A \cdot B$

Which is the output of on AND gate.

115. (*) Bonus

$Y = \overline{\overline{A.B}} = \overline{\overline{A}+\overline{B}} = \overline{\overline{A}}+\overline{\overline{B}} = \overline{A}+\overline{B}$

Truth table

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

116. (*c*) As there is single input in option (*c*).

117. (*a*) $Y = \overline{\overline{AB} \bullet A} = \overline{\overline{AB}} + \overline{\overline{A}}$

$= AB + \overline{A} = 0 + 0 = 0$

118. (*a*)

119. (*c*) $Y = \overline{(A.\overline{AB}).(B+\overline{AB})}$

$Y = \overline{\overline{A.\overline{AB}}+\overline{(B+\overline{AB})}}$

$\Rightarrow Y = A.\overline{AB}+\overline{B}.AB$

$Y = A\overline{A}+A\overline{B}+AB\overline{B}$

$Y = A\overline{B}$

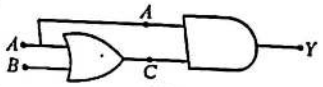
120. (*c*) To make output 1

$P + Q$ must be 0

$P + Q = (\overline{x}+y)+(y+\overline{x})$.

So, $x = 1, y = 0$ will give $P + Q = 0$

121. (*a*)



C = A + B and $Y = \overline{A.C}$

A	B	C = (A + B)	A.C.	$Y = \overline{A.C}$
0	0	0	0	1
0	1	1	0	1
1	0	1	1	0
1	1	1	1	0

@FAKE_CBSE X @RAJ_EDUNET

2024 JEE Advanced Solved Paper

Physics Paper-1

SECTION 1 (Maximum Marks: 12)

- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (*a*), (*b*), (*c*) and (*d*). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 If **ONLY** the correct option is chosen;
Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);
Negative Marks : –1 In all other cases.

1. A dimensionless quantity is constructed in terms of electronic charge e, permittivity of free space ε_0, Planck's constant h, and speed of light c. If the dimensionless quantity is written as $e^{\alpha}\varepsilon_0^{\beta}h^{\gamma}c^{\delta}$ and n is a non-zero integer, then $(\alpha, \beta, \gamma, \delta)$ is given by

(*a*) $(2n, -n, -n, -n)$ (*b*) $(n, -n, -2n, -n)$
(*c*) $(n, -n, -n, -2n)$ (*d*) $(2n, -n, -2n, -2n)$

2. An infinitely long wire, located on the z-axis, carries a current I along the $+z$-direction and produces the magnetic field $\vec{B}$. The magnitude of the line integral $\int \vec{B}\cdot\vec{dl}$ along a straight line from the point $(-\sqrt{3}a, a, 0)$ to $(a, a, 0)$ is given by

[μ_0 is the magnetic permeability of free space.]

(*a*) $7\mu_0 I/24$ (*b*) $7\mu_0 I/12$
(*c*) $\mu_0 I/8$ (*d*) $\mu_0 I/6$

3. Two beads, each with charge q and mass m, are on a horizontal, frictionless, non-conducting, circular hoop of radius R. One of the beads is glued to the hoop at some point, while the other one performs small oscillations about its equilibrium position along the hoop. The square of the angular frequency of the small oscillations is given by [ε_0 is the permittivity of free space.]

(*a*) $q^2/\left(4\pi\varepsilon_0 R^3 m\right)$ (*b*) $q^2/\left(32\pi\varepsilon_0 R^3 m\right)$
(*c*) $q^2/\left(8\pi\varepsilon_0 R^3 m\right)$ (*d*) $q^2/\left(16\pi\varepsilon_0 R^3 m\right)$

4. A block of mass 5 kg moves along the x-direction subject to the force $F = (-20x + 10)$N, with the value of x in metre. At time $t = 0$s, it is at rest at position $x = 1$ m. The position and momentum of the block at $t = (\pi\backslash 4)$s are

(*a*) –0.5 m, 5 kg m/s (*b*) 0.5 m, 0 kg m/s
(*c*) 0.5 m, –5 kg m/s (*d*) –1 m, 5 kg m/s

SECTION 2 (Maximum Marks: 12)

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (*a*), (*b*), (*c*) and (*d*). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 **ONLY** if (all) the correct option(s) is(are) chosen;
Partial Marks : +3 If all the four options are correct but **ONLY** three options are chosen;
Partial Marks : +2 If three or more options are correct but **ONLY** two options are chosen, both of which are correct;
Partial Marks : +1 If two or more options are correct but **ONLY** one option is chosen and it is a correct option;
Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);
Negative Marks: –2 In all other cases.

- For example, in a question, if (*a*), (*b*) and (*d*) are the **ONLY** three options corresponding to correct answers, then
  choosing ONLY (*a*), (*b*) and (*d*) will get +4 marks;
  choosing ONLY (*a*) and (*b*) will get +2 marks;
  choosing ONLY (*a*) and (*d*) will get +2 marks;
  choosing ONLY (*b*) and (*d*) will get +2 marks;
  choosing ONLY (*a*) will get +1 mark;
  choosing ONLY (*b*) will get +1 mark;
  choosing ONLY (*d*) will get +1 mark;
  choosing no option (i.e. the question is unanswered) will get 0 marks; and choosing any other combination of options will get –2 marks.

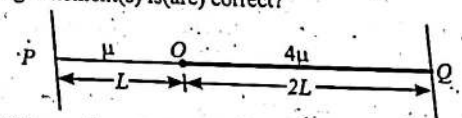
@FAKE CBSE X @RAJ EDUNET

5. A particle of mass m is moving in a circular orbit under the influence of the central force $F(r) = -kr$, corresponding to the potential energy $V(r) = kr^2/2$, where k is a positive force constant and r is the radial distance from the origin. According to the Bohr's quantization rule, the angular momentum of the particle is given by $L = n\hbar$, where $\hbar = h/(2\pi)$, h is the Planck's constant, and n a positive integer. If v and E are the speed and total energy of the particle, respectively, then which of the following expression(s) is(are) correct?

(a) $r^2 = n\hbar\sqrt{\dfrac{1}{mk}}$ (b) $v^2 = n\hbar\sqrt{\dfrac{k}{m^3}}$

(c) $\dfrac{L}{mr^2} = \sqrt{\dfrac{k}{m}}$ (d) $E = \dfrac{n\hbar}{2}\sqrt{\dfrac{k}{m}}$

6. Two uniform strings of mass per unit length μ and 4μ, and length L and $2L$, respectively, are joined at point O, and tied at two fixed ends P and Q, as shown in the figure. The strings are under a uniform tension T. If we define the frequency $\nu_0 = \dfrac{1}{2L}\sqrt{\dfrac{T}{\mu}}$, which of the following statement(s) is(are) correct?



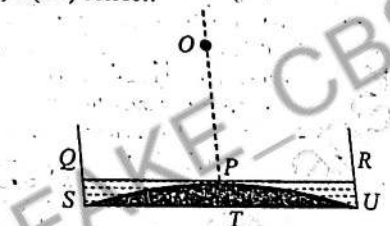
(a) With a node at O, the minimum frequency of vibration of the composite string is ν_0.

(b) With an antinode at O, the minimum frequency of vibration of the composite string is $2\nu_0$.

(c) When the composite string vibrates at the minimum frequency with a node at O, it has 6 nodes, including the end nodes.

(d) No vibrational mode with an antinode at O is possible for the composite string.

7. A glass beaker has a solid, plano-convex base of refractive index 1.60, as shown in the figure. The radius of curvature of the convex surface (SPU) is 9 cm, while the planar surface (STU) acts as a mirror. This beaker is filled with a liquid of refractive index n up to the level QPR. If the image of a point object O at a height of h (OT in the figure) is formed onto itself, then, which of the following option(s) is(are) correct?



(a) For $n = 1.42$, $h = 50$ cm. (b) For $n = 1.35$, $h = 36$ cm.

(c) For $n = 1.45$, $h = 65$ cm. (d) For $n = 1.48$, $h = 85$ cm.

SECTION 3 (Maximum Marks: 24)

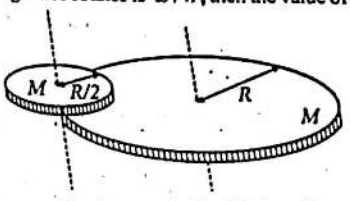
- This section contains SIX (06) questions.
- The answer to each question is a NON-NEGATIVE INTEGER.
- For each question, enter the correct integer corresponding to the answer using the mouse and the on screen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 If ONLY the correct integer is entered;

Zero Marks : 0 In all other cases.

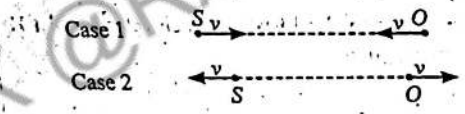
8. The specific heat capacity of a substance is temperature dependent and is given by the formula $C = kT$, where k is a constant of suitable dimensions in SI units, and T is the absolute temperature. If the heat required to raise the temperature of 1 kg of the substance from −73°C to 27°C is nk, the value of n is _____.
[Given: 0 K = −273°C]

9. A disc of mass M and radius R is free to rotate about its vertical axis as shown in the figure. A battery operated motor of negligible mass is fixed to this disc at a point on its circumference. Another disc of the same mass M and radius $R/2$ is fixed to the motor's thin shaft. Initially, both the discs are at rest. The motor is switched on so that the smaller disc rotates at a uniform angular speed ω. If the angular speed at which the large disc rotates is ω/n, then the value of n is _____.



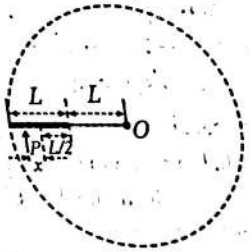
10. A point source S emits unpolarized light uniformly in all directions. At two points A and B, the ratio $r = I_A/I_B$ of the intensities of light is 2. If a set of two polaroids having 45° angle between their pass-axes is placed just before point B, then the new value of r will be _____.

11. A source (S) of sound has frequency 240 Hz. When the observer (O) and the source move towards each other at a speed v with respect to the ground (as shown in Case 1 in the figure), the observer measures the frequency of the sound to be 288 Hz. However, when the observer and the source move away from each other at the same speed v with respect to the ground (as shown in Case 2 in the figure), the observer measures the frequency of sound to be n Hz. The value of n is _____.



12. Two large, identical water tanks, 1 and 2, kept on the top of a building of height H, are filled with water up to height h in each tank. Both the tanks contain an identical hole of small radius on their sides, close to their bottom. A pipe of the same internal radius as that of the hole is connected to tank 2, and the pipe ends at the ground level. When the water flows from the tanks 1 and 2 through the holes, the times taken to empty the tanks are t_1 and t_2, respectively. If $H = \left(\dfrac{16}{9}\right)h$, then the ratio t_1/t_2 is _____.

13. A thin uniform rod of length L and certain mass is kept on a frictionless horizontal table with a massless string of length L fixed to one end (top view is shown in the figure). The other end of the string is pivoted to a point O. If a horizontal impulse P is imparted to the rod at a distance $x = L/n$ from the mid-point of the rod (see figure), then the rod and string revolve together around the point O, with the rod remaining aligned with the string. In such a case, the value of n is _____.



@FAKE_CBSE_@RAJEEV_MNET

SECTION 4 (Maximum Marks: 12)

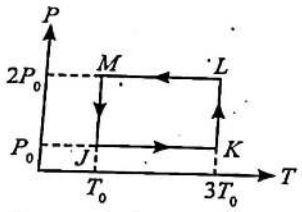
- This section contains **FOUR (04)** Matching List Sets.
- Each set has **ONE** Multiple Choice Question.
- Each set has **TWO** lists: **List-I** and **List-II**.
- **List-I** has **Four** entries (P), (Q), (R) and (S) and **List-II** has **Five** entries (1), (2), (3), (4) and (5).
- **FOUR** options are given in each Multiple Choice Question based on **List-I** and **List-II** and **ONLY ONE** of these four options satisfies the condition asked in the Multiple Choice Question.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 **ONLY** if the option corresponding to the correct combination is chosen;

Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);

Negative Marks : –1 In all other cases.

14. One mole of a monatomic ideal gas undergoes the cyclic process $J \to K \to L \to M \to J$, as shown in the P-T diagram.



Match the quantities mentioned in **List-I** with their values in **List-II** and choose the correct option.

[R is the gas constant.]

List-I		List-II	
(P)	Work done in the complete cyclic process	(1)	$RT_0 - 4RT_0\ln 2$
(Q)	Change in the internal energy of the gas in the process JK	(2)	0
(R)	Heat given to the gas in the process KL	(3)	$3RT_0$
(S)	Change in the internal energy of the gas in the process MJ	(4)	$-2RT_0\ln 2$
		(5)	$-3RT_0\ln 2$

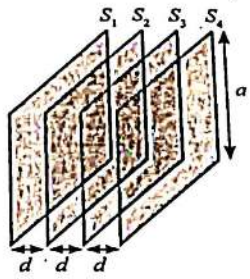
(a) P → 1; Q → 3; R → 5; S → 4

(b) P → 4; Q → 3; R → 5; S → 2

(c) P → 4; Q → 1; R → 2; S → 2

(d) P → 2; Q → 5; R → 3; S → 4

Four identical thin, square metal sheets, S_1, S_2, S_3 and S_4, each of side a are kept parallel to each other with equal distance $d(\ll a)$ between them, as shown in the figure. Let $C_0 = \varepsilon_0 a^2 / d$, where ε_0 is the permittivity of free space.



Match the quantities mentioned in List-I with their values in List-II and choose the correct option.

List-I		List-II	
(P)	The capacitance between S_1 and S_4, with S_2 and S_3 not connected, is	(1)	$3C_0$
(Q)	The capacitance between S_1 and S_4, with S_2 shorted to S_3, is	(2)	$C_0/2$
(R)	The capacitance between S_1 and S_3, with S_2 shorted to S_4, is	(3)	$C_0/3$
(S)	The capacitance between S_1 and S_2, with S_3 shorted to S_1, and S_2 shorted to S_4, is	(4)	$2C_0/3$
		(5)	$2C_0$

(a) P → 3; Q → 2; R → 4; S → 5

(b) P → 2; Q → 3; R → 2; S → 1

(c) P → 3; Q → 2; R → 4; S → 1

(d) P → 3; Q → 2; R → 2; S → 5

16. A light ray is incident on the surface of a sphere of refractive index n at an angle of incidence θ_0. The ray partially refracts into the sphere with angle of refraction ϕ_0 and then partly reflects from the back surface. The reflected ray then emerges out of the sphere after a partial refraction. The total angle of deviation of the emergent ray with respect to the incident ray is α. Match the quantities mentioned in List-I with their values in List-II and choose the correct option.

List-I		List-II	
(P)	If $n = 2$ and $\alpha = 180°$, then all the possible values of θ_0 will be	(1)	30° and 0°
(Q)	If $n = \sqrt{3}$ and $\alpha = 180°$, then all the possible values of θ_0 will be	(2)	60° and 0°
(R)	If $n = \sqrt{3}$ and $\alpha = 180°$, then all the possible values of ϕ_0 will be	(3)	45° and 0°
(S)	If $n = \sqrt{2}$ and $\theta_0 = 45°$, then all the possible values of α will be	(4)	150°
		(5)	0°

(a) P → 5; Q → 2; R → 1; S → 4

(b) P → 5; Q → 1; R → 2; S → 4

(c) P → 3; Q → 2; R → 1; S → 4

(d) P → 3; Q → 1; R → 2; S → 5

CHAITANYA CBT EXAM @RAJ_LDUMET

SECTION 4 (Maximum Marks: 12)

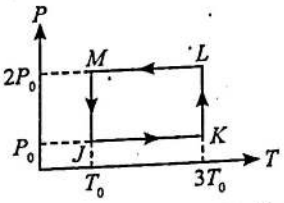
- This section contains **FOUR (04)** Matching List Sets.
- Each set has **ONE** Multiple Choice Question.
- Each set has **TWO** lists: **List-I** and **List-II**.
- **List-I** has **Four** entries (P), (Q), (R) and (S) and **List-II** has **Five** entries (1), (2), (3), (4) and (5).
- **FOUR** options are given in each Multiple Choice Question based on **List-I** and **List-II** and **ONLY ONE** of these four options satisfies the condition asked in the Multiple Choice Question.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : **+3 ONLY** if the option corresponding to the correct combination is chosen;

Zero Marks : **0** If none of the options is chosen (i.e. the question is unanswered);

Negative Marks : **–1** In all other cases.

14. One mole of a monatomic ideal gas undergoes the cyclic process $J \to K \to L \to M \to J$, as shown in the P-T diagram.



Match the quantities mentioned in **List-I** with their values in **List-II** and choose the correct option.

[R is the gas constant.]

	List-I		List-II
(P)	Work done in the complete cyclic process	(1)	$RT_0 - 4RT_0\ln 2$
(Q)	Change in the internal energy of the gas in the process JK	(2)	0
(R)	Heat given to the gas in the process KL	(3)	$3RT_0$
(S)	Change in the internal energy of the gas in the process MJ	(4)	$-2RT_0\ln 2$
		(5)	$-3RT_0\ln 2$

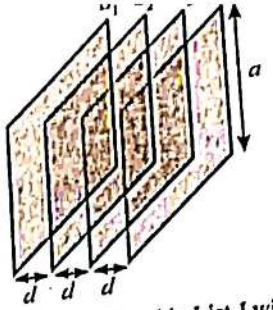
(*a*) P → 1; Q → 3; R → 5; S → 4

(*b*) P → 4; Q → 3; R → 5; S → 2

(*c*) P → 4; Q → 1; R → 2; S → 2

(*d*) P → 2; Q → 5; R → 3; S → 4

15. Four identical thin, square metal sheets, S_1, S_2, S_3 and S_4, each of side a are kept parallel to each other with equal distance $d(\ll a)$ between them, as shown in the figure. Let $C_0 = \varepsilon_0 a^2 / d$, where ε_0 is the permittivity of free space.



Match the quantities mentioned in List-I with their values in List-II and choose the correct option.

	List-I		List-II
(P)	The capacitance between S_1 and S_4, with S_2 and S_3 not connected, is	(1)	$3C_0$
(Q)	The capacitance between S_1 and S_4, with S_2 shorted to S_3, is	(2)	$C_0/2$
(R)	The capacitance between S_1 and S_3, with S_2 shorted to S_4, is	(3)	$C_0/3$
(S)	The capacitance between S_1 and S_2, with S_3 shorted to S_4, and S_2 shorted to S_4, is	(4)	$2C_0/3$
		(5)	$2C_0$

(*a*) P → 3; Q → 2; R → 4; S → 5

(*b*) P → 2; Q → 3; R → 2; S → 1

(*c*) P → 3; Q → 2; R → 4; S → 1

(*d*) P → 3; Q → 2; R → 2; S → 5

16. A light ray is incident on the surface of a sphere of refractive index n at an angle of incidence θ_0. The ray partially refracts into the sphere with angle of refraction ϕ_0 and then partly reflects from the back surface. The reflected ray then emerges out of the sphere after a partial refraction. The total angle of deviation of the emergent ray with respect to the incident ray is α. Match the quantities mentioned in List-I with their values in List-II and choose the correct option.

	List-I		List-II
(P)	If $n = 2$ and $\alpha = 180°$, then all the possible values of θ_0 will be	(1)	30° and 0°
(Q)	If $n = \sqrt{3}$ and $\alpha = 180°$, then all the possible values of θ_0 will be	(2)	60° and 0°
(R)	If $n = \sqrt{3}$ and $\alpha = 180°$, then all the possible values of ϕ_0 will be	(3)	45° and 0°
(S)	If $n = \sqrt{2}$ and $\theta_0 = 45°$, then all the possible values of α will be	(4)	150°
		(5)	0°

(*a*) P → 5; Q → 2; R → 1; S → 4

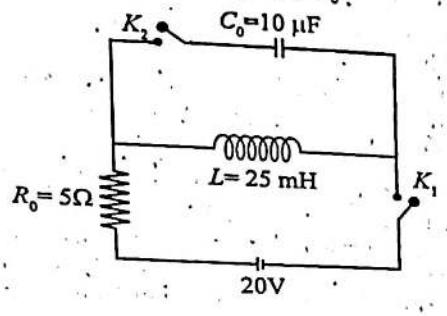
(*b*) P → 5; Q → 1; R → 2; S → 4

(*c*) P → 3; Q → 2; R → 1; S → 4

(*d*) P → 3; Q → 1; R → 2; S → 5

@RAJ_EDUNET

17. The circuit shown in the figure contains an inductor L, a capacitor C_0, a resistor R_0 and an ideal battery. The circuit also contains two keys K_1 and K_2. Initially, both the keys are open and there is no charge on the capacitor. At an instant, key K_1 is closed and immediately after this the current in R_0 is found to be I_1. After a long time, the current attains a steady state value I_2. Thereafter, K_2 is closed and simultaneously K_1 is opened and the voltage across C_0 oscillates with amplitude V_0 and angular frequency ω_0.



Match the quantities mentioned in List-I with their values in List-II and choose the correct option.

	List-I		List-II
(P)	The value of I_1 in Ampere is	(1)	0
(Q)	The value of I_2 in Ampere is	(2)	2
(R)	The value of ω_0 in kilo-radians/s is	(3)	4
(S)	The value of V_0 in Volt is	(4)	20
		(5)	200

(a) P → 1; Q → 3; R → 2; S → 5
(b) P → 1; Q → 2; R → 3; S → 5
(c) P → 1; Q → 3; R → 2; S → 4
(d) P → 2; Q → 5; R → 3; S → 4

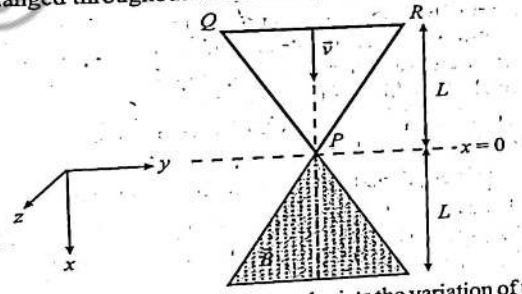
Physics Paper-2

SECTION 1 (Maximum Marks: 12)

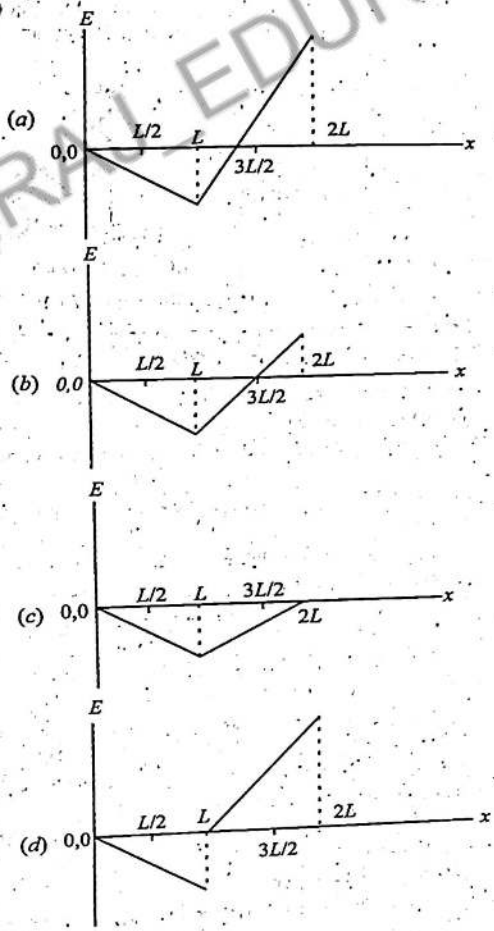
- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (*a*), (*b*), (*c*) and (*d*). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 If **ONLY** the correct option is chosen;
Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);
Negative Marks : −1 In all other cases.

1. A region in the form of an equilateral triangle (in x-y plane) of height L has a uniform magnetic field $\vec{B}$ pointing in the z-direction. A conducting loop PQR, in the form of an equilateral triangle of the same height L, is placed in the x-y plane with its vertex P at $x = 0$ in the orientation shown in the figure. At $t = 0$, the loop starts entering the region of the magnetic field with a uniform velocity $\vec{v}$ along the +x-direction. The plane of the loop and its orientation remain unchanged throughout its motion.



Which of the following graph best depicts the variation of the induced emf (E) in the loop as a function of the distance (x) starting from $x = 0$?



@RAJEDUNET

2. A particle of mass m is under the influence of the gravitational field of a body of mass M ($>> m$). The particle is moving in a circular orbit of radius r_0 with time period T_0 around the mass M. Then, the particle is subjected to an additional central force, corresponding to the potential energy $V_c(r) = m\alpha/r^3$, where α is a positive constant of suitable dimensions and r is the distance from the center of the orbit. If the particle moves in the same circular orbit of radius r_0 in the combined gravitational potential due to M and $V_c(r)$, but with a new time period T_1, then $(T_1^2 - T_0^2)/T_1^2$ is given by

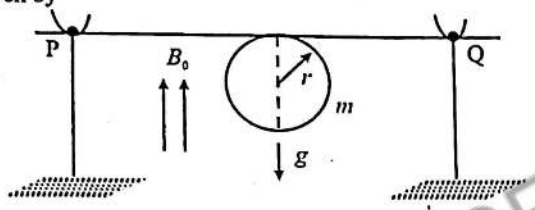
[G is the gravitational constant.]

(a) $\frac{3\alpha}{GMr_0^2}$ (b) $\frac{\alpha}{2GMr_0^2}$ (c) $\frac{\alpha}{GMr_0^2}$ (d) $\frac{2\alpha}{GMr_0^2}$

3. A metal target with atomic number $Z = 46$ is bombarded with a high energy electron beam. The emission of X-rays from the target is analyzed. The ratio r of the wavelengths of the K_α-line and the cut-off is found to be $r = 2$. If the same electron beam bombards another metal target with $Z = 41$, the value of r will be

(a) 2.53 (b) 1.27 (c) 2.24 (d) 1.58

4. A thin stiff insulated metal wire is bent into a circular loop with its two ends extending tangentially from the same point of the loop. The wire loop has mass m and radius r and it is in a uniform vertical magnetic field B_0, as shown in the figure. Initially, it hangs vertically downwards, because of acceleration due to gravity g, on two conducting supports at P and Q. When a current I is passed through the loop, the loop turns about the line PQ by an angle θ given by



(a) $\tan\theta = \pi r I B_0/(mg)$ (b) $\tan\theta = 2\pi r I B_0/(mg)$

(c) $\tan\theta = \pi r I B_0/(2mg)$ (d) $\tan\theta = mg/(\pi r I B_0)$

SECTION 2 (Maximum Marks: 12)

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (a), (b), (c) and (d). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 **ONLY** if (all) the correct option(s) is(are) chosen;

Partial Marks : +3 If all the four options are correct but **ONLY** three options are chosen;

Partial Marks : +2 If three or more options are correct but **ONLY** two options are chosen, both of which are correct;

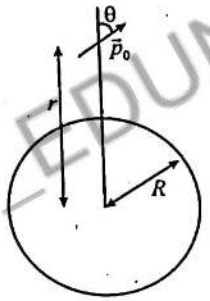
Partial Marks : +1 If two or more options are correct but **ONLY** one option is chosen and it is a correct option;

Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);

Negative Marks: –2 In all other cases.

- For example, in a question, if (A), (B) and (D) are the **ONLY** three options corresponding to correct answers, then
  choosing ONLY (a), (b) and (d) will get +4 marks;
  choosing ONLY (a) and (b) will get +2 marks;
  choosing ONLY (a) and (d) will get +2 marks;
  choosing ONLY (b) and (d) will get +2 marks;
  choosing ONLY (a) will get +1 mark;
  choosing ONLY (b) will get +1 mark;
  choosing ONLY (d) will get +1 mark;
  choosing no option (i.e. the question is unanswered) will get 0 marks; and choosing any other combination of options will get –2 marks.

5. A small electric dipole $\vec{p}_0$, having a moment of inertia I about its center, is kept at a distance r from the center of a spherical shell of radius R. The surface charge density σ is uniformly distributed on the spherical shell. The dipole is initially oriented at a small angle θ as shown in the figure. While staying at a distance r, the dipole is free to rotate about its center.



If released from rest, then which of the following statement(s) is (are) correct?

[ε_0 is the permittivity of free space.]

(a) The dipole will undergo small oscillations at any finite value of r.

(b) The dipole will undergo small oscillations at any finite value of $r > R$.

(c) The dipole will undergo small oscillations with an angular frequency of $\sqrt{\frac{2\sigma p_0}{\epsilon_0 I}}$ at $r = 2R$.

(d) The dipole will undergo small oscillations with an angular frequency of $\sqrt{\frac{\sigma p_0}{100\,\epsilon_0 I}}$ at $r = 10R$.

6. A table tennis ball has radius $(3/2) \times 10^{-2}$ m and mass $(22/7) \times 10^{-3}$ kg. It is slowly pushed down into a swimming pool to a depth of $d = 0.7$ m below the water surface and then released from rest. It emerges from the water surface at speed v, without getting wet, and rises up to a height H. Which of the following option(s) is (are) correct?

[Given: $\pi = 22/7$, $g = 10\ ms^{-2}$, density of water $= 1 \times 10^3\ kg\ m^{-3}$, viscosity of water $= 1 \times 10^{-3}$ Pa-s.]

(a) The work done in pushing the ball to the depth d is 0.077 J.

(b) If we neglect the viscous force in water, then the speed $v = 7$ m/s.

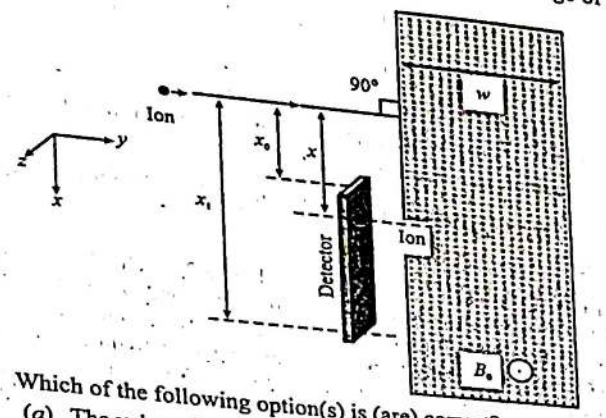
(c) If we neglect the viscous force in water, then the height $H = 1.4$ m.

(d) The ratio of the magnitudes of the net force excluding the viscous force to the maximum viscous force in water is 500/9.

@MAKE_CBSE_X_@RAJ_EDUNET

7. A positive, singly ionized atom of mass number A_M is accelerated from rest by the voltage 192 V. Thereafter, it enters a rectangular region of width w with magnetic field $\vec{B}_0 = 0.1\hat{k}$ Tesla, as shown in the figure. The ion finally hits a detector at the distance x below its starting trajectory.

[Given: Mass of neutron/proton = $(5/3) \times 10^{-27}$ kg, charge of the electron = 1.6×10^{-19} C.]



Which of the following option(s) is (are) correct?

(a) The value of x for H^+ ion is 4 cm.

(b) The value of x for an ion with $A_M = 144$ is 48 cm.

(c) For detecting ions with $1 \le A_M \le 196$, the minimum height $(x_1 - x_0)$ of the detector is 55 cm.

(d) The minimum width w of the region of the magnetic field for detecting ions with $A_M = 196$ is 56 cm.

SECTION 3 (Maximum Marks: 24)

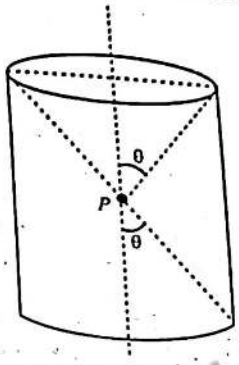
- This section contains SIX (06) questions.
- The answer to each question is a NON-NEGATIVE INTEGER.
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- For each question, enter the correct integer corresponding to the answer using the mouse and the onscreen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 If ONLY the correct integer is entered;
Zero Marks : 0 In all other cases.

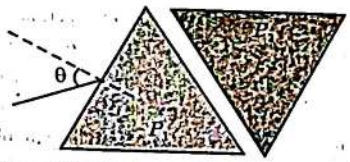
8. The dimensions of a cone are measured using a scale with a least count of 2 mm. The diameter of the base and the height are both measured to be 20.0 cm. The maximum percentage error in the determination of the volume is _____.

9. A ball is thrown from the location $(x_0, y_0) = (0, 0)$ a horizontal playground with an initial speed v_0 at an angle θ_0 from the $+x$-direction. The ball is to be hit by a stone, which is thrown at the same time from the location $(x_1, y_1) = (L, 0)$. The stone is thrown at an angle $(180 - \theta_1)$ from the $+x$-direction with a suitable initial speed. For a fixed v_0, when $(\theta_0, \theta_1) = (45°, 45°)$, the stone hits the ball after time T_1 and when $(\theta_0, \theta_1) = (60°, 30°)$, it hits the ball after time T_2. In such a case, $(T_1/T_2)^2$ is _____.

10. A charge is kept at the central point P of a cylindrical region. The two edges subtend a half-angle θ at P, as shown in the figure. When $\theta = 30°$, then the electric flux through the curved surface of the cylinder is Φ If $\theta = 60°$, then the electric flux through the curved surface becomes $\Phi / \sqrt{n}$, where the value of n is _____.

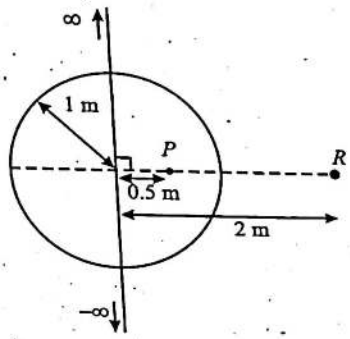


11. Two equilateral-triangular prisms P_1 and P_2 are kept with their sides parallel to each other, in vacuum, as shown in the figure. A light ray enters prism P_1 at an angle of incidence θ such that the outgoing ray undergoes minimum deviation in prism P_2. If the respective refractive indices of P_1 and P_2 are $\sqrt{\frac{3}{2}}$ and $\sqrt{3}$, then $\theta = \sin^{-1}\left[\sqrt{\frac{3}{2}}\sin\left(\frac{\pi}{\beta}\right)\right]$, where the value of β is _____.



12. An infinitely long thin wire, having a uniform charge density per unit length of 5 nC/m, is passing through a spherical shell of radius 1 m, as shown in the figure. A 10 nC charge is distributed uniformly over the spherical shell. If the configuration of the charges remains static, the magnitude of the potential difference between points P and R, in Volt, is .

[Given: In SI units $\frac{1}{4\pi\epsilon_0} = 9 \times 10^9$, ln 2 = 0.7. Ignore the area pierced by the wire.]



@JEE_CBT_@PAPERSUNET

13. A spherical soap bubble inside an air chamber at pressure $P_0 = 10^5$ Pa has a certain radius so that the excess pressure inside the bubble is $\Delta P = 144$ Pa. Now, the chamber pressure is reduced to $8P_0/27$ so that the bubble radius and its excess pressure change. In this process, all the temperatures remain unchanged. Assume air to be an ideal gas and the excess pressure ΔP in both the cases to be much smaller than the chamber pressure. The new excess pressure ΔP in Pa is _____.

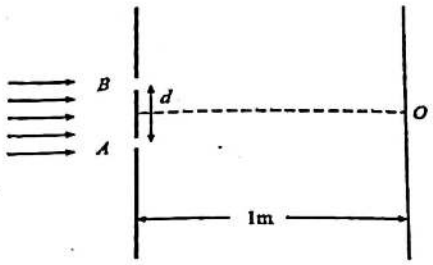
SECTION 4 (Maximum Marks: 12)

- This section contains **TWO (02)** paragraphs.
- Based on each paragraph, there are **TWO (02)** questions.
- The answer to each question is a **NUMERICAL VALUE.**
- For each question, enter the correct numerical value of the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
- If the numerical value has more than two decimal places, **truncate/round-off** the value to **TWO** decimal places.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 **ONLY** if the option corresponding to the correct combination is chosen;

Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);

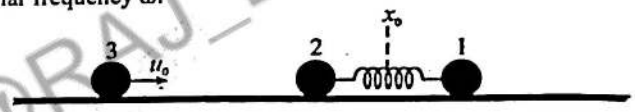
Paragraph (Q. 14-15): In a Young's double slit experiment, each of the two slits A and B, as shown in the figure, are oscillating about their fixed center and with a mean separation of 0.8 mm. The distance between the slits at time t is given by $d = (0.8 + 0.04 \sin \omega t)$ mm, where $\omega = 0.08$ rad s^{-1}. The distance of the screen from the slits is 1 m and the wavelength of the light used to illuminate the slits is 6000 Å. The interference pattern on the screen changes with time, while the central bright fringe (zeroth fringe) remains fixed at point O.



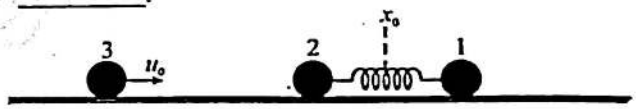
14. The 8th bright fringe above the point O oscillates with time between two extreme positions. The separation between these two extreme positions, in micrometer (μm), is _____.

15. The maximum speed in μm/s at which the 8th bright fringe will move is _____.

Paragraph (Q. 16-17): Two particles, 1 and 2, each of mass m, are connected by a massless spring, and are on a horizontal frictionless plane, as shown in the figure. Initially, the two particles, with their center of mass at x_0, are oscillating with amplitude a and angular frequency ω. Thus, their positions at time t are given by $x_1(t) = (x_0 + d) + a \sin \omega t$ and $x_2(t) = (x_0 - d) - a \sin \omega t$, respectively, where $d > 2a$. Particle 3 of mass m moves towards this system with speed $u_0 = a\omega/2$, and undergoes instantaneous elastic collision with particle 2, at time t_0. Finally, particles 1 and 2 acquire a center of mass speed v_{cm} and oscillate with amplitude b and the same angular frequency ω.



16. If the collision occurs at time $t_0 = 0$, the value of $v_{cm}/(a\omega)$ will be _____.



17. If the collision occurs at time $t_0 = \pi/(2\omega)$, then the value of $4b^2/a^2$ will be _____.

@FAKE_CBSE_X @RAJ_EXPERT

Solutions Paper-1

1. (*a*) Given $[\epsilon^a \epsilon_0^b h c^d] = M^0 L^0 T^0 A^0$

$[AT]^a \ [M^{-1}L^{-3}T^4A^2]^b [ML^2T^{-1}]^c [LT^{-1}]^d$
$= M^0 L^0 T^0 A^0$

Equating powers both sides

$\Rightarrow \alpha + 2\beta = 0$ ... (*i*)

$-\beta + \gamma = 0$ ... (*ii*)

$-3\beta + 2\gamma + \delta = 0$ ... (*iii*)

$\alpha + 4\beta + \gamma - \delta = 0$ ... (*iv*)

Solving all equations, we get

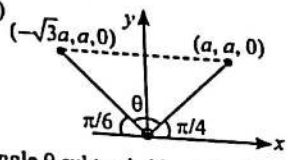
$\Rightarrow \alpha = -2\beta$

$\gamma = \beta$

$\delta = \beta$

$(-2\beta, \beta, \beta, \beta)$

2. (*a*)



Angle θ subtended by dotted line at centre

$= \frac{7\pi}{12}$

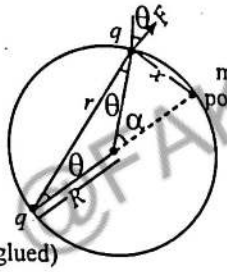
$\int \vec{B} \cdot \vec{dl}$ along the straight line will be

$= \frac{\mu_0 (i)}{2\pi} \times \theta = \frac{\mu_0 i}{2\pi} \times \frac{7\pi}{12}$

$\Rightarrow \int \vec{B} \cdot \vec{dl} = \frac{7\mu_0 i}{24}$

Option (*a*) is correct answer.

3. (*b*) Bead is displaced a little by x from mean position.



Here $r = 2R\cos\theta$

Also $\alpha = 2\theta$

$\Rightarrow \alpha = \frac{\phi}{2}$ also $x = R\alpha$

Coulomb's force on charge at a distance r between them

$= \frac{Kq^2}{r^2}$

Force towards mean position $= \frac{Kq^2}{r^2}\sin\theta$

acceleartion $= \frac{-Kq^2}{mr^2}\sin\theta = \frac{-Kq^2 \cdot \sin\theta}{m4R^2\cos^2\theta}$

$\Rightarrow a_x = -\frac{Kq^2}{4mR^2\left(\frac{\theta}{2}\right)}\sin\left(\frac{\alpha}{2}\right) = \frac{-Kq^2}{4mR^2}\frac{1}{2}\frac{x}{R}$

$= \omega^2 \cdot x$

[as α is small]

So $\sin\left(\frac{\alpha}{2}\right) = \frac{\alpha}{2}$

So, $\boxed{\omega^2 = \frac{q^2}{32\pi\epsilon_0 mR^3}}$

Option (*b*) is correct answer

4. (*c*) $F = (-20x + 10)N$ and $m = 5$ kg

So, $a = -\frac{20x+10}{5} = -4x + 2$

[from newton's law]

$a = \frac{vdv}{dx} = 4x + 2$

Integration both sides

$\int_0^v v dv = \int_1^x (-4x+2)dx \rightarrow \frac{v^2}{2} = [-2x^2 + 2x]_1^x$

$\Rightarrow v = -2\sqrt{x - x^2}$

$\Rightarrow \frac{dx}{dt} = -2\sqrt{x - x^2}$

$\Rightarrow \int_{x=1}^{x=x} \frac{dx}{\sqrt{x - x^2}} = -2\int_0^{\pi/4} dt$

$\sin^{-1}[2x-1]_1^x = -\frac{\pi}{2} \Rightarrow x = .5m$

Momentum at $x = 1/2$

$= mV = mV(x = .5m) = 5 \times (-2\sqrt{.5 - .5^2})$

$= -5kg - m/s$

Hence correct option (*c*)

5. (*a,b,c*) Angular momentum $= nh$

$L = mvr = nh$,

Centripetal force $= kr$

$\frac{mv^2}{r} = kr$

$mv^2 = kr^2$

$m^2v^2 = mkr^2 \Rightarrow mv = \sqrt{mkr^2}$

$\Rightarrow mvr = r^2\sqrt{mk}$

$nh = r^2\sqrt{mk}$ [As $mvr = nh$]

$\frac{nh}{\sqrt{mk}} = r^2$ ... (*i*)

So, option (*a*) is correct

$\frac{mv^2}{r} = kr$

$\Rightarrow v^2 = \frac{kr^2}{m}$

Using eqn (i)

$= \frac{nh}{\sqrt{mk}}\frac{k}{m} = v^2 = nh\sqrt{\frac{k}{m^3}}$

option (*b*) is correct

$\frac{L}{mr^2} = \frac{h\sqrt{mk}}{mnh}$ [using eqn (*i*)]

$\frac{L}{mr^2} = \sqrt{\frac{k}{m}}$

option (*c*) is correct

Total energy = P.E + K.E

$= \frac{1}{2}kr^2 + \frac{1}{2}kr^2$

using eqn (i)

$E = kr^2 = k\frac{nh}{\sqrt{mk}}$

$= nh\sqrt{\frac{k}{m}}$

Hence, option (*d*) is incorrect

6. (*a,c,d*) Case - node at O

Assume m^{th} harmonic in left and n^{th} harmonic in right string

Equating frequency in both string

$= m\frac{1}{2l}\sqrt{\frac{T}{\mu}} = n\frac{1}{2(2l)}\sqrt{\frac{T}{4\mu}}$

$\Rightarrow m = \frac{n}{2} \times \frac{1}{2}$

$\Rightarrow \frac{m}{n} = \frac{1}{4} \Rightarrow m = 1, n = 4$

Total nodes = 6

(*c* is correct)

Case– antinode at O

$m = \frac{1}{4l}\sqrt{\frac{T}{\mu}} = n\frac{1}{4(2l)}\sqrt{\frac{T}{4\mu}}$

$\Rightarrow \frac{m}{n} = \frac{1}{2} \times \frac{1}{2} \Rightarrow \frac{m}{n} = \frac{1}{4} \Rightarrow \therefore m = 1$

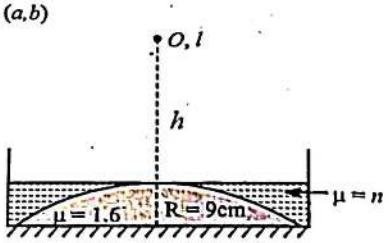
minimum frequency $= 1\frac{1}{4l}\sqrt{\frac{T}{\mu}}\sqrt{\frac{T}{\mu}} = \frac{v_0}{2}$

So, (*b*) option is incorrect

a, *c*, *d* are correct

@FAKE_CBSE_X @RAJ_EDUNET

7. (*a,b*)



Whole system will act as concave mirror, say, image is formed at h then

$-h = 2(f_{eff})$

equating effective power

$$\Rightarrow -\frac{1}{f_{eff}} = 2\left(\frac{1}{f_{liq}}\right)+2\left(\frac{1}{2_{lens}}\right)+\left(\frac{-1}{f_{mirror}}\right) \quad \ldots (i)$$

$$-\frac{1}{f_{eff}} = 2\left(\frac{n-1}{9}\right)+2\left(\frac{0.6}{9}\right)+\left(-\frac{1}{\infty}\right) \quad \ldots (ii)$$

From (i) and (ii)

$$h = \frac{9}{(1.6-n)}$$

Putting values of n and h, we see only option a and b satisfy this relation

So, a and b are correct

8. (25000) $c = \frac{dQ}{mdT}$

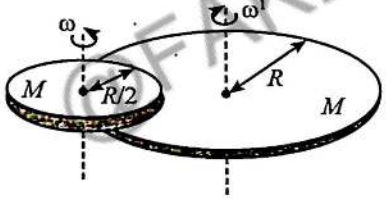
$\Rightarrow dQ = m \cdot C \cdot dT$

$= 1 \cdot kTdT \quad [m = 1\text{ kg}]$

$$Q\int dQ \doteq \int_{200}^{300} kTdT = \frac{k}{2}[300^2 - 200^2]$$

$= 25000\text{k} \Rightarrow n = 25000$

9. (12) No external torque, so angular momentum is conserved, conserving it about dotted axis of bigger disc.



$$\frac{MR^2}{2}\omega' + M \cdot R\omega' \cdot R + \frac{M(R/2)^2}{2}\omega = 0$$

ω' : required angular speed.

$$\Rightarrow \frac{3}{2}MR^2\omega' = \frac{-MR^2\omega}{8}$$

$$\Rightarrow \omega' = -\frac{\omega}{12}$$

$\Rightarrow n = 12$

10. (8) Intensity $\alpha \frac{1}{x^2}$

x : distance from point source

$$\Rightarrow \frac{I_A}{I_B} = \frac{x_B^2}{x_A^2} = 2 \Rightarrow x_B = \sqrt{2}x_A$$

So B is farther than A Due to polaroid intensity at B will change not at A

Using Malus Law

New intensity at $B = \frac{I_0}{2}\cos^2 45° = \frac{I_0}{4}$

$\Rightarrow$ Ratio becomes 4 times.

$\Rightarrow$ new $r = 8$

11. [200] Case-1 apparent frequency f

$$f' = f\left(\frac{c+v}{c-v}\right)$$

$$\Rightarrow 288 = 240\left(\frac{c+v}{c-v}\right) \quad \ldots (i)$$

Case-2 apparent frequency f''

$$f'' = f\left(\frac{c-v}{c+v}\right)$$

$$n = 240\left(\frac{c-v}{c+v}\right) \quad \ldots (ii)$$

$n = 200$ Hz

12. [3] Time to empty α tank from initial level h_i to final level h_f is given by formula

$$T = \frac{2A}{a\sqrt{2g}}\left(\sqrt{h_i} - \sqrt{h_f}\right)$$

For Case of tank 1:

$h_i = h, h_f = 0$

$$T_1 = \frac{2A}{a\sqrt{2g}}\left(\sqrt{h}\right)$$

For Case of tank 2:

$$h_f = \frac{16h}{9}, h_f = h + H = \frac{25h}{9}$$

$$T_2 = \frac{2A\sqrt{h}}{2\sqrt{2g}}\left(\frac{5}{3} - \frac{4}{3}\right) = \frac{2A\sqrt{h}}{2\sqrt{2g}} \times \frac{1}{3}$$

$$\frac{T_1}{T_2} = 3$$

13. [18] Moment of Inertia of rod about centre

$$(O) = \frac{mL^2}{12} + m\left(L + \frac{L}{2}\right)^2$$

$$I = \frac{7mL^2}{3.}$$

Angular impulse = Change in Angular momentum

Angular impulse about O

$$= P\left(x + \frac{3L}{2}\right) = I\omega_0 \quad \ldots (i)$$

Linear impulse $= mv_c = P \quad \ldots (ii)$

Where $v_c = \frac{3L}{2}\omega_0 \quad \ldots (iii)$

from eqn (*i*), (*ii*) & (*iii*)

$$m\left(\frac{3L}{2}\omega_0\right)\left(x + \frac{3L}{2}\right) = \frac{7}{3}mL^2.\omega_0$$

$$x + \frac{3L}{2} = \frac{14}{9}L \Rightarrow n = \frac{L}{18}$$

14. (*b*) For M to J, process is i so thermal

$W = nRT$ in 2

$= RT_0$ In 2

$\Delta U = 0$

For J to K, process is isobaric

$W = nR(3T_0 - T_0)$

$W = 2RT_0$

$\Delta U = nC_v\Delta T$

$$= \frac{3R}{2} \times 2T_0 = 3RT_0$$

For K to L process is i isothermal

$W = -nR(3T_0)$ in 2

$W = -3RT_0$ In 2

$\Delta U = 0$

$Q = -3RT_0$ in 2

For L to M, process is isobaric

$W = nR(T_0 - 3T_0)$

$W = -2RT_0$

$\Delta U = nC_v\Delta T$

$$= n \times \frac{3R}{2} \times (-2T_0)$$

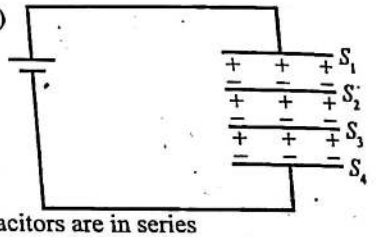
$= -3RT_0$

Total work done $= RT_0$ In $2 + 2RT_0 - 3RT_0$ In $2 - 2RT_0$

$= -2RT_0$ In 2

So, $P \to 4, Q \to 3, R \to 5, S \to 2$

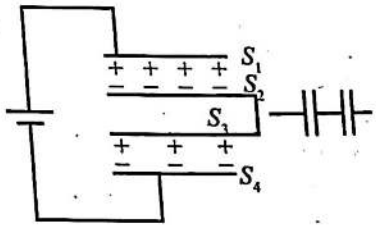
15. (*c*) (*P*)



Capacitors are in series

$C_{eq} = \frac{C_0}{3} \Rightarrow P \to (3)$

(*Q*)

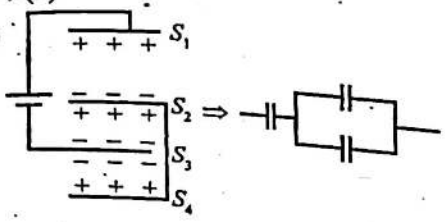


$C_{eq} = \frac{C_0}{2}$

@FAKE_CBSE_X @RAJ_EDUNET

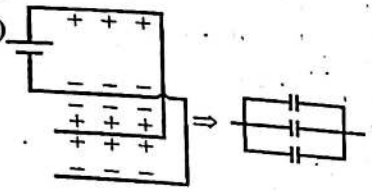
$Q \rightarrow (2)$

(R)



$$C_{eq} = \frac{2C}{3} \Rightarrow R \rightarrow (4)$$

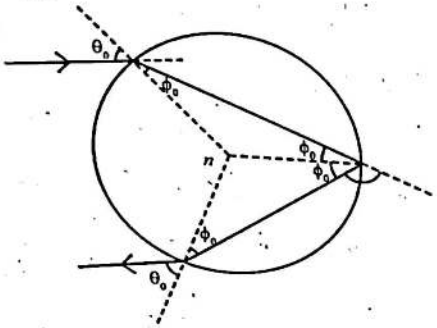
(S)



$\Rightarrow C_{eq} = 3C_0$

$S \rightarrow (1)$

16. (a)



Total deviation

$\alpha = (\theta_0 - \phi_0) + (\pi - 2\phi_0) + (\theta_0 - \phi_0)$

$\alpha = \pi + 2\theta_0 - 4\phi_0$

$\sin\theta_0 = n\sin\phi_0$ ... (i)

(P), $\alpha = 180$, $n = 2$ ... (ii)

if $\alpha = \pi$, $2\theta_0 - 4\phi_0 = 0$

$\theta_0 - 2\phi_0$

$$\sin\theta_0 = 2\sin\left(\frac{\theta_0}{2}\right)$$

$P \rightarrow (5)$

Q, $n = \sqrt{3}$, $\alpha = 180$

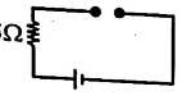
$\theta_0 - 2\phi_0$

$Q \rightarrow (2)$

$$\sin\theta_0 = \sqrt{3}\sin\left(\frac{\theta_0}{2}\right)$$

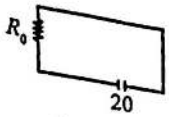
$\theta_0 - 60, 0°$

17. (a) Just after closing K_1, inductor can be removed



$i_1 = 0, \Rightarrow P \rightarrow (1)$

After, long time, inductor acts as short circuit..

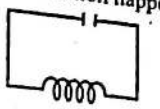


$$I_2 = \frac{20}{5} = 4A, \Rightarrow Q \rightarrow (3)$$

After opening K_1 R

Closing K_2, $L - C$

Oscillation happens



$$\omega = \frac{1}{\sqrt{LC}}$$

$$= \frac{1}{\sqrt{24\times10^{-3}\times10\times10^{-6}}}$$

$\omega = 2000$ rad/s

$\omega = 2$ k rad/s $\Rightarrow R \rightarrow (2)$

$i_0 = 4$

$$Q_0 = \frac{i_0}{\omega} = \frac{4}{2\times10^3} = 2mC$$

$$\therefore V_0 = \frac{Q_0}{C} = \frac{2\times10^3}{10} = 200$$

$\Rightarrow S \rightarrow (5)$

Solutions Paper-2

1. (b) $\tan\left(\sin^{-1}\left(\frac{3}{5}\right) - 2\cos^{-1}\left(\frac{2}{\sqrt{5}}\right)\right)$

Let $\sin^{-1}\frac{3}{5} = \alpha \Rightarrow \sin\alpha = \frac{3}{5}$

$\Rightarrow \tan\alpha = \frac{3}{4}$

$$2\cos^{-1}\left(\frac{2}{\sqrt{5}}\right) = \beta \Rightarrow \cos\frac{\beta}{2} = \frac{2}{\sqrt{5}}$$

$$\Rightarrow \tan\frac{\beta}{2} = \frac{1}{2}$$

$$\tan\beta = \frac{2\tan\frac{\beta}{2}}{1-\tan^2\frac{\beta}{2}} = \frac{2\times\frac{1}{2}}{1-\frac{1}{4}} = \frac{4}{3}$$

$$\Rightarrow \tan(\alpha-\beta) = \frac{\tan\alpha - \tan\beta}{1+\tan\alpha\tan\beta}$$

$$= \frac{\frac{3}{4}-\frac{4}{3}}{1+\frac{3}{4}\cdot\frac{4}{3}} = \frac{\frac{-7}{12}}{\frac{2}{1}} = \frac{-7}{24}$$

2. (b) $y^2 = 4x$ ... (i)

$y^2 = 12 - 2x$ ... (ii)

From (i) and (ii), we get

$\Rightarrow 4x = 12 - 2x$

$\Rightarrow x = 2$

Putting $x = 2$ in equation (i), we get

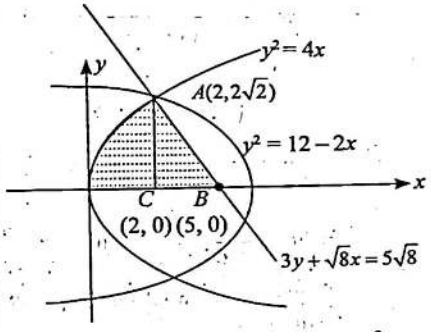
$y^2 = 4\times2 \Rightarrow y = 2\sqrt{2}$

$$A = \int_0^2 2\sqrt{x}dx + \frac{1}{2}\times3\times2\sqrt{2}$$

$$\Rightarrow A = 2\left(\frac{x^{3/2}}{3/2}\right)_0^2 + 3\sqrt{2} = \frac{4}{3}(2)^{3/2} + 3\sqrt{2}$$

$$\Rightarrow A = \frac{17}{3}\sqrt{2} \quad \text{... } (iii)$$

Compare equation (iii) with $A = \alpha\sqrt{2}$, we get $\alpha = \frac{17}{3}$.



3. (b) $I = \lim_{x\to0^+}(\sin(\sin kx) + \cos x + x)^{\frac{2}{x}} = e^6$

$$\Rightarrow \ln I = \lim_{x\to0^+}\frac{2}{x}(\sin(\sin kx) + \cos x + x - 1)$$

@FAKE_CBSE_X @RAJEDUNET

17. [0.25]

From solution 16,

$$I_1 = 2\int_0^{\frac{\pi}{2}} f(x)g(x)dx = \int_0^{\frac{\pi}{2}} g(x)dx$$

$$\text{Now, } I_1 = \int_0^{\frac{\pi}{2}} g(x)dx = \int_0^{\frac{\pi}{2}} \sqrt{\frac{\pi}{2}x - x^2}\,dx$$

$$I_1 = \int_0^{\frac{\pi}{2}} \sqrt{\left(\frac{\pi}{4}\right)^2 - \left(\frac{\pi}{4} - x\right)^2}\,dx$$

$$\text{Put } \frac{\pi}{4} - x = t$$

$$\Rightarrow -dx = dt \Rightarrow dx = -dt$$

$$I_1 = -\int_{\frac{\pi}{4}}^{-\frac{\pi}{4}} \sqrt{\left(\frac{\pi}{4}\right)^2 - t^2}\,dt = \int_{-\frac{\pi}{4}}^{\frac{\pi}{4}} \sqrt{\left(\frac{\pi}{4}\right)^2 - t^2}\,dt$$

$$I_1 = 2\int_0^{\frac{\pi}{4}} \sqrt{\left(\frac{\pi}{4}\right)^2 - t^2}\,dt$$

$$= 2\left[\frac{t}{2}\sqrt{\left(\frac{\pi}{4}\right)^2 - t^2} + \frac{\pi^2}{32}\sin^{-1}\left(\frac{4t}{\pi}\right)\right]_0^{\frac{\pi}{4}}$$

$$I_1 = 2\left[\frac{\pi}{8}\times 0 + \frac{\pi^2}{32}\cdot\frac{\pi}{2} - 0 - 0\right] = \frac{\pi^3}{32}$$

$$\text{Now, } I = \frac{8}{\pi^3} I_1 = \frac{8}{\pi^3}\times\frac{\pi^3}{32} = \frac{1}{4}$$

Hence, $I = 0.25$

@FAKE_CBSE_X @RAJ_EDUNET